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EXPERIENCE WITH A PRODUCER GAS PLANT.

BY HARRY L. THOMAS, ASSISTANT SUPERINTENDENT, HINGHAM WATER COMPANY, HINGHAM, MASS.

[*Read January 8, 1908.*]

In presenting this paper I do so with a considerable degree of timidity when I realize that the duty falls upon me to introduce to this Association the application of producer gas to the needs of our business as water-works superintendents and officials, and it would undoubtedly have been wiser had a more general treatise been first presented by an eminent authority, to be followed by the experience papers of us " small fry." But I wish in no way to question the wisdom or judgment of our worthy secretary, by whose urgent request this matter is presented, and the announcement borne upon the notice for this meeting, " Experience with a Producer Gas Plant," will surely lead you gentlemen to anticipate nothing but an account of the most ordinary everyday experiences which have come to us in the management of our new station and its equipment. Whatever is here presented is but a meager part of our experience. There is much that can better be told to an attentive ear than recorded in this paper; therefore should I fail to make clear the descriptions, and this treatise fall short of your expectations, rest assured that at any time you feel inclined to pay us a visit, by dropping us a line at the office in advance, my time and an automobile will very gladly be placed at the disposal of any of you gentlemen.

Our plant was installed in the spring of 1906, the test being made in May of that year. It is located at Fulling Mill Pond, one of our

sources of supply, and during the summer season, when the greatest demand is made on the system, is used to pump water to the receiving basin at the Weir River Station through 20 000 feet of 14-, 12-, and 10-inch pipe. From there the water is again pumped into the distributing system by a Deane steam pump. Lest surprise be felt at the handling of the water twice over, let me explain that it is contemplated to, in the near future, dispense with our steam plant, and by increasing the number of units of the producer plant, and providing suitable mains, do all our pumping at Fulling Mill Pond.

The entire equipment, producer, engine, and pump, was furnished and installed under contract by the Olds Gas Power Company, of Lansing, Mich., and consists of a Pintsch system suction gas producer of size to furnish sufficient gas to generate 70 horsepower; a 65 horse-power, single cylinder, Olds heavy duty, type K gas engine; a 13 × 12 Smith-Vaile single-acting, outside packed plunger, triplex pump; and a compressed air starting outfit. The foundations, furnished by the water company, are of concrete, and the whole is housed in a wooden frame building 30 × 36 feet, situated 50 feet from a collecting well 40 feet in diameter and 20 feet deep, from which the water is pumped, and so placed that the center line of the pump is parallel to, and 15 feet from, the 14-inch pipe leading from the well. The building, which is temporary, built to accommodate the present unit until such time as others are added, is very plain, as the photograph will show, and is divided into two rooms by a tight partition running from floor to roof, separating the engine and pump from the producer, made necessary by the unavoidable dust and ashes consequent upon cleaning the fire in the generator.

The photographs which are reproduced in Plates I and II show what the machines look like, but can hardly give a definite idea of their relative arrangement, and in order to make this clear we will consider it for a moment by beginning in the producer room. This is 30 × 13 feet, the floor being for the most part of brick, as in cleaning the fire some live coals are very apt to roll out. First stands the generator in which the gas is made. It is cylindrical in form, 3 feet 6 inches diameter by 7 feet 6 inches high, inside measures, and is supported by three iron legs which raise

FIG. 1. FULLING MILL POND PUMPING STATION, HINGHAM WATER CO.

FIG. 2. CHARGING FLOOR, SHOWING CHARGING HOPPER OF GENERATOR.

it 2 feet from the floor. It is lined with courses of properly molded fire brick 8 inches in thickness, the joints being made up with fire clay. Between the shell and this lining is a space of 1 inch, and after each course of brick was laid this space was very carefully filled with mineral wool to avoid the possibility of any air working in and either affecting the composition of the gas or creating an air pocket to retard the flow of the same. The bottom course of brick rests upon the frame supporting the shaking grate, which is funnel-shaped, provided with a draw center. On either side of the generator are two doors, one above the other, the upper one opening at the top of the grate, allowing space for cleaning and poking the fire, the lower one giving opportunity for shaking and drawing the grate when necessary to work out an accumulation of clinker. From the bottom of the generator a tube 10 inches in diameter leads down to a water-sealed ash pit, thus enabling the removal of ashes without admitting an undue amount of air into the fire. Such is the nature of producer gas that the proper amount of air admitted to the fire is of vital importance, and unless great care is exercised, perplexing results are inevitable. In operation we have sometimes found that under certain conditions of fire and fuel the opening of the fire or grate doors for more than half a minute at a time was impossible without producing trouble.

The generator is filled and fed from the top, for this purpose a cast-iron charging hopper being provided which will hold 85 pounds of coal. When charging becomes necessary the hopper is filled, its cover closed and fastened, and it is then swung around until it comes over a hole in the center of the top, when the coal simply runs down into the fire; the hopper is then swung back ready to receive another charge. By means of a ground joint this hopper is self-sealed, again guarding against improper admission of air.

At one side of the generator is situated an apparatus for injecting steam and air into the fire. These are both admitted through the same pipe into the ash tube previously referred to, and the present apparatus, which has replaced that originally attached, is most satisfactory in its working. It is provided with proper valves to regulate both air and steam.

Standing beside the generator is the vaporizer, cast iron, of the independent type, having a water-sealed cleaning pot and a relief chimney to the atmosphere. In this is generated the steam for use in the fire. It is cylindrical in form and built in three sections bolted together, the bottom part providing the seal for the generator as well as a cleaning pot for the vaporizer itself. The middle section contains a number of 1-inch tubes surrounded by water, and during operation the hot gas passing down through these tubes generates the steam, which passes to the injector before alluded to through a 1½-inch pipe leading out from the upper section, which is provided with a water jacket to which is attached a gage glass and overflow pipe. The gas port from the generator comes into this upper section, and is reached for cleaning by removing the flat top of the vaporizer, which also gives access to the tubes when it becomes necessary to brush them. Connected with the bottom section is the relief or chimney pipe.

Next stands the scrubber, provided with a grate placed about 18 inches from the bottom, and from this to the filling door near the top this is filled with clean egg size coke. Through its top projects a 1¼-inch pipe, having on its end a perforated ball from which, during operation, a spray of water is constantly pouring. In this machine the gas gets its principal cleaning and is cooled by the water spray, more or less water being used as the temperature of the gas requires.

The next and last machine through which the gas passes is the cleaner or dry scrubber, which is fitted with two grates, one above the other, 8 inches apart, upon which are evenly distributed clean mill shavings to the depth of 3 inches, and to prevent these dropping through the grates, coarse mesh burlap is laid on. It is 4 feet 8 inches in diameter, so made that the whole top may be lifted to provide easy access for cleaning. In our plant we consider this machine plays a most important part in preparing the gas for the engine by removing any tar, carbon, or dirt which may pass along with the gas, thereby assuring cleaner valves, gas ports, and combustion chamber than could reasonably be expected without this cleaning; and great pains are taken that the filling of shavings shall at all times be evenly distributed and the layers of proper thickness. When at any time evidence of dirty gas is found, our first care is given to this machine.

FIG. 1. PRODUCER ROOM, SHOWING GENERATOR, VAPORIZER, SCRUBBER, AND CLEANER.

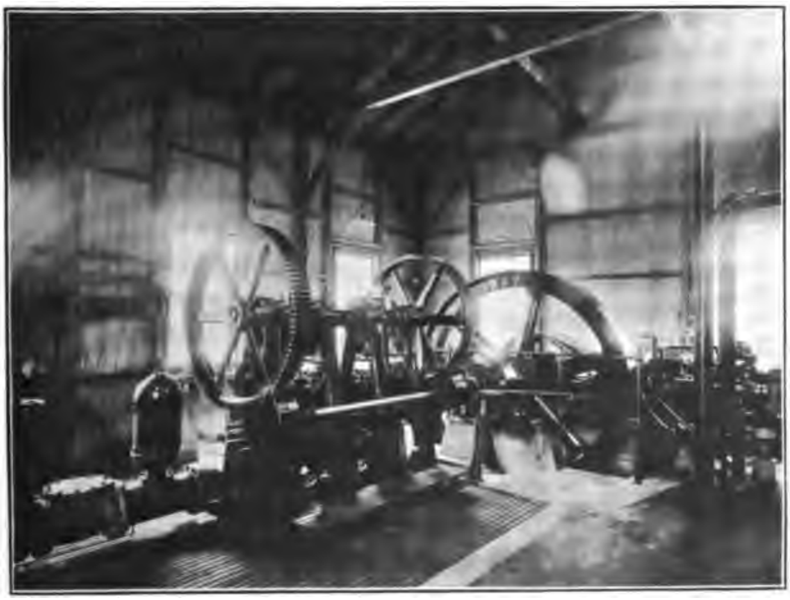


FIG. 2. ENGINE AND PUMP ROOM.

The four machines just described constitute what is termed the producer, from the fact that they all figure in the preparation of the gas. In the same room with these is the compressed air starting outfit, comprising a small compressor driven by a belt from a gasoline engine with the necessary storage tank. Belted to this same engine is the blower used when starting the fire in the generator.

The engine, four cycle, single cylinder, is very compactly built, measuring approximately 11 feet × 4 feet 3 inches; the top of the governor, which is the highest point, being 5 feet from the floor, and the fly wheel, 9 feet in diameter with a 12-inch face, weighing 8 000 pounds. The crank shaft is 6 inches in diameter in bearings, the main and outboard bearings being of the ring oiler type with babbitt-lined boxes. The connecting rod is a solid steel forging, fitted at the crank end with a babbitted box and at the wrist pin end with a phosphor bronze box. When originally installed, the crank pin was oiled by a centrifugal oil ring fastened to the crank cheek and fed from a sight feed oiler, but after numerous experiences with a hot crank pin, melted box linings, etc., this was replaced by a wiper, and a great source of trouble and worry removed. For lubricating the wrist pin, piston, and exhaust valve stem, a sight feed pressure pump attached to the engine bed and operated by the side shaft is used. The speed is regulated by a Jahn's governor working on the common air and gas valve, and ignition is furnished by a Bosch magneto.

The pump, which is of the triplex geared type, is connected with the engine by a friction clutch and, when running at rated speed of forty-two revolutions per minute, will deliver one and one quarter million gallons in twenty-four hours, this being the duty which will be required of this unit when the contemplated plant is complete.

I shall assume that for the purposes of this paper the foregoing descriptions are sufficient, but if they prove not to be, perhaps more can be brought out in any discussion which may follow, and it may be well to now consider briefly the matter of generating the gas and its progress to the engine.

A wood fire is first built, and when this is well going, anthracite pea coal is put in until the generator is filled to its full capacity, 1 260 pounds. As soon as practicable the blower is applied, but

we are always careful not to blow too hard with a fresh fire, as it is an easy matter to overheat the grate, particularly if coke is used for a foundation. In our practice we never start the plant with an absolutely fresh fire, — not that it cannot be done if necessary, but we prefer to have a cooler fire to work with, which we get by building it up slowly until in proper condition and then allowing it to stand over night. During the building up of the fire, and until the proper quality of gas is obtained, the chimney pipe is kept wide open to provide draft and an outlet for waste gases, and under ordinary conditions an hour's blowing is necessary.

In order to test the gas a ⅜-inch cock is tapped into the lower section of the vaporizer above the water seal, and when the gas from this will burn with a firm, full blue flame having a yellow tip, we consider we have it in sufficient quantity and proper quality to be blown over to the engine. If, however, when testing, we get an all-yellow flame, experience prompts us to let that gas go up chimney, as it is so hot that it cannot be properly cooled before reaching the engine; and should we start with it, preignition would inevitably result, attended by uncomfortable circumstances.

Having obtained a good test of gas at the generator, we are now ready to blow over. Tapped into the gas main near the engine is a 1½-inch pipe which is fitted with a plug stop and running out to the atmosphere; and near this pipe is placed a second test cock. With the blower still running, this pipe is opened, the water seal emptied, and the chimney pipe closed. This allows all the gas to be carried through the various machines to the engine, with the relief at the engine instead of at the generator as before. When good gas comes from this cock the water seal at the generator is refilled, chimney pipe opened, and a few minutes more of blowing, to be sure that the generator is well filled and the fire hot, makes us ready to start.

Right here it may be of interest to follow the course of gas to the engine. It leaves the generator at the top, entering the vaporizer at its top and, passing down through the tubes, passes out at the bottom. As has already been said, in passing through the tubes it generates the steam, which under good conditions

takes about thirty minutes. Then entering the scrubber at the bottom, it is drawn up through the coke, where it is met by the spray of water before mentioned, and, passing out through the port at the top, is drawn through the gas main to the top of the cleaner. Here it passes through the shavings and escapes through the bottom to the engine. In its entire course it is drawn along by the suction of the engine piston, and it is, therefore, quite impossible that any gas can escape; and it also becomes imperative, for the same reason, that no leaky joint or fixture shall admit of any air being drawn in at other than legitimate places.

Having blown the generator hot, as we term it, with a view to starting, the water seal is again emptied, chimney pipe closed, one of the fire doors opened just a little to be sure that some vent for gas confined in the generator is provided, and the throttle valve in the gas main at the engine opened. The engine is then started by compressed air, and under favorable conditions, after three or four revolutions, we get explosions in the combustion chamber; the air is shut off, the lever which controls timing of ignition properly adjusted, and our engine is fairly under way. But alas! one very important detail has been omitted from the rather confusing sequence of maneuvers, and I ask you kindly to assume that the wire connecting magneto and igniter has been put in place, with the humble assurance that not only was it omitted from the proper place in this narrative but, to the inexpressible chagrin of all concerned, it has sometimes been omitted in actual practice. (This was in the early days.) The generator door is now tightly closed, the air feed pipe from atmosphere opened, blower pipe shut off, the clutch pulley thrown in, and the several oil and bearing cups adjusted for the day. After the engine has been fairly under way the water is turned on for the scrubber spray, the proper feeding of which is very essential.

As closely as I can transcribe them, these are the steps taken in starting up the engine and pump, and the next topic might naturally relate to our experiences, sublime, ridiculous, and exasperating, and which, in justice to the subject as announced, perhaps should have formed the sole and important body of this paper. I trust my descriptions have in no great degree been tiresome to you, for I felt that a certain amount were necessary that you might

better follow my thought; and that those unaccustomed to such installations could gain a faint idea of the make-up of this particular system of gas producer.

The proposal offered by the firm that installed our plant includes among others the following clause:

"We are to furnish a representative to operate the plant for thirty days after the installation, whose duty it will be to properly instruct such representatives as you may appoint in the duties involved in the successful operation of both producer and engine."

What would have happened had not such instruction been placed at our disposal can, I assure you, be better imagined than recorded, for, in spite of the persistent and patient efforts of the aforesaid representative of the party of the first part to imprint upon the memory wise and serious truths, after the expiration of the aforesaid thirty days the aforesaid representatives of the party of the second part were promptly and on divers occasions "stuck for fair." Whereupon aforesaid representatives of the party of the second part did loudly and wildly utter such strange and unseemly language as would be unbecoming in this transcript. I am not breaking confidences when I relate any of our experiences, and lest any of you may be apprehensive, let me say that we have, for our purpose, an excellent plant, doing good continuous service and, under the charge of two reliable engineers, keeping well up to the standard of economy and efficiency for which such claims were made.

A very early difficulty encountered was the proper handling of the fire, and many times, after looking everywhere else for the source of the trouble, we were brought face to face with poor conditions at the generator, with gas of insufficient quantity and inferior quality. The experience of both operators as steam engineers was of no material benefit, and frequently the stoking bar was hung up with a bang, accompanied by the remark, "I thought I knew how to run a fire, but, after all, I guess I don't." They did understand running a steam boiler, but this was an entirely new process of firing, to be mastered only by failures and hard knocks, and we pride ourselves that now we have, in great measure, conquered the difficulty, and while a change in the grade of coal may occasionally cause slight inconvenience, we are able to cope

with it in an understanding manner and without disastrous results.

Under favorable conditions of fuel, the body of incandescent coal is about 18 or 20 inches deep, and the gas, carbon monoxide, is generated by the proper combining of certain elements during the passage of air and steam through the fire. But the proper combining in the early days was an uncertain quantity, and the entry in the record book by our engineer, " Started engine 8 A.M., ran ten minutes, and then fainted," recalls vividly to my mind many a heart-rending scene which resembled the time when, in younger days, we got the swing well under way and then stood to " let the old cat die."

Now the conditions which led up to this entry were these: The fire had been blown as usual and gas of good quality had been tested at both cocks; but at the end of the ten minutes all the gas had been exhausted from the machines, and what was being generated was not sufficient to supply the wants of the engine. This lack of gas was due to the presence in the fire of a large amount of hard clinker, and the clinker had been caused by improper proportioning of steam and air under the grate. Had more steam been admitted, while possibly clinker might have been present, it would have been at least porous, and the choking of the flow of gas reduced.

Again, the air was furnishing the major quantity of oxygen consumed, and its other element, nitrogen, an inert gas, was present in sufficient volume to displace other gases necessary for combustion. The record states that several trials were made to start, with similar results, and further attempts were abandoned until the fire had been thoroughly overhauled, which was accomplished by slicing from the top through a poke hole provided for that purpose, and using great care that any clinker attached to the lining was broken off. Then from the fire doors, by the use of a hooked bar, these were withdrawn and the generator filled with fresh coal, after which the blower was applied and the usual course pursued. It may be best to say here that the clinker which did the mischief had been accumulating during the run on the previous day, thereby leaving us a dirty fire with which to start.

Equally perplexing results were experienced later in our oper-

ating, and I again refer to the engineer's record book and find there entered, " Fourth of July for five minutes; then ran nice for a few minutes. At 8.25 down and out." Gentlemen, the utter abandon which prompted this entry can only be appreciated by those who, while working in ignorance and struggling with inexperience, try to make themselves and others believe that at last they understand operating a producer gas plant, and the cause of this entry may naturally be spoken of now. Whereas in the previous case steam was lacking, the difficulty was now due to an over-abundance of it, together with a hot fire; and the highly explosive hydro-carbons, which were in excess, were taken over to the engine and very heavy explosions occurred, which could not only be heard, but plainly felt in the vibration of the combustion chamber end of the engine. At the particular time in question, pre-ignition also contributed to the general fuss, brought about by a dirty combustion chamber, and from the fact that the heavy charge was ignited in the chamber before the admission valve was wholly closed, the force of the explosion was felt way back to the cleaner, where the shavings were disturbed by the current passing in the opposite direction from that intended. The noise produced by these explosions was extremely loud, both in the gas main and exhaust pipe, and when it occurred, as it sometimes did, during a calm summer night, the neighbors a mile distant became alarmed lest our quiet old town had been attacked by a battery of twelve-pounders. The explosions would continue for three or four minutes in rapid succession, during which time we cudgeled our brains for a cause, and usually resulted, as recorded by the engineer, in stopping the engine.

By the aid of the representative of the party of the first part we soon came to understand that here again we must look to the generator for the seat of difficulty and cool the fire; at the same time reduce the steam. " But," we argued, " we were told that we must have steam to cool the fire, and in order to get that quickly for the purpose we must have a hot fire, and hot fire and steam give this result. What is to be done? " Well, the only thing that could be done just then was to cut off the steam and run chances that our fuel would not clinker badly until matters came to rights and we again had command of the situation. In

this case, also, ignorance allowed us to let the fire get beyond us and become so hot that steam in sufficient quantity to cool it did its own peculiar mischief. I am free to say that of all the " kinks " accompanying the plant, this one of proper firing is by far the most important, and one which no amount of instruction and reading, unless accompanied by experience, can make plain, very many details of fuel, fire, air, and steam under varying conditions having a direct bearing upon results.

To aid in selecting fuel, calorimeter tests were made, with the result that the sample first selected contained 13 150 British thermal units per pound of dry coal, and during the test of the plant and for some time after this gave good results. The second purchase was made after a sample was tested, showing 12 998 B. T. U. per pound of dry coal and 8.4 per cent. ash; but a radical change in the condition of the fire became apparent by its use, and despite our best efforts we could not keep it cool. Another new feature appeared in the shape of a very deep body of incandescent coal, and it seemed impossible to prevent the fire working up high in the generator. This was first noted when, after running the bar up into the fire, no fresh coal would follow down. The clinker removed was of an entirely different character; it came out in large patches like masses of soft rubber, finally accumulating, despite our efforts, in a solid mass at the top of the fire doors that would nearly support the entire body of fuel. Steam was being admitted, we knew, in maximum quantity for safety, and the engine, while it continued to run, was pulling for gas very hard. Against all reason and practice, in order to ease up this pull, the fire was poked from the top every half hour, and it was observed that the hole made by the poke bar remained open and that the blowing of excess steam from the safety valve also stopped. We were brought to conclude, therefore, that the fire was filled with this mass of peculiar soft clinker, and that when the bar was withdrawn chimneys of hot gas, which are most undesirable, were formed, and not only was the fire, by reason of the frequent pokings, burning high, but we were making hot gas and paving the way for more Fourth of July stunts, which soon spoke for themselves.

But luck comes to every one sometime, and while shut down for

an hour to clean valves and change igniters we noticed a heavy deposit resembling sulphur in appearance and odor, and the thought came to me that I had read that sulphur was a great enemy to a gas producer. Reference proved my memory correct, and here we had the explanation of our difficulty, for the sulphur, which usually occurs as iron sulphide, in melting had formed a base around which clinkers had formed in vast quantities, and any effort to prevent this would prove futile. The ultimate result was that the fire was drawn from the generator, and the coal for future running was purchased and still is purchased from a local dealer who furnishes us pea coal screened from the various bins on his wharf, which is proving excellent for our use. Coal with a high per cent. of ash can be used very nicely if the percentage of sulphur is low, but the foregoing experience easily proves what may happen if sulphur is present in excessive proportion.

Other experiences by which we have profited have come to us and are still coming: adjustments of admission and mixing valves; the best point for ignition under varying circumstances; proper amount of oil required to lubricate piston without overfeeding and consequent burning; regulation of water spray in scrubber; care of cleaner with a view to preventing any considerable amount of dirt or carbon being carried to the engine; methods by which "back fires" may be quickly and quietly stopped, if not prevented; and numerous others which it seems not necessary to detail, as they vary with us, as they would anywhere else with local conditions of plant and fuel. Those I have spoken of are, I am satisfied, very likely to fall to the lot of any one who, as we have, operates a producer gas plant without any previous experience, unless an abundance of good luck comes his way.

The results obtained from the plant are most satisfactory. Our longest continuous run to date was made from 5.15 A.M. November 24, to 1.50 A.M. December 4, 1907, 235¾ hours; the plant had been in operation since November 2 and the stop was made for the purpose of cleaning the mixing valve and changing igniters, which occupied two hours. This was not planned in any way as a record run; our engineer assures me that it was not absolutely necessary to stop when he did, but we had shortly before this been troubled with dirty gas, and we were curious to note what effect,

if any, had been produced by increasing the amount of shavings in the cleaner. Much to our satisfaction it had proved to be of great benefit. Our plant is now running 24 hours a day, and we are pumping 1¼ million gallons with a coal consumption of 1 100 pounds. The record for yesterday was 62 440 revolutions; the total head, including suction lift, was 108.4 feet; coal fired, 1 085 pounds. This gives a duty of 107.6 million foot pounds per one hundred pounds of coal. The cost of coal per ton was $4.67. The cost of coal per ton used at the steam plant is $5.50, so that in order to compare the efficiency of the two plants on a basis of dollars and cents, it would be necessary to add nearly eighteen per cent. to the duty of the gas plant, which will bring this duty up to 126.6 million. While no test has been made at the steam plant, my belief is that its duty will not exceed 40 million, so that fuel cost of pumping by steam is three times that of pumping by producer gas. During the test of the producer gas plant its duty per one hundred pounds of coal fired exceeded 135 million.

I desire to call your attention now, if I have not before, to the fact that we are pumping against but 110 feet total head, while the unit is designed to work against from 160 to 170 feet total head, which it did during the test above mentioned; also to say that while the engine is now running under a little more than half load, the duty would be materially increased were it running up to rated capacity.

And now, gentlemen, I feel that to say more in this paper may be needless. I reiterate what was said in the beginning, that much can better be told than written, and I renew what I assure you was a hearty and genuine invitation.

DISCUSSION.

MR. E. H. GOWING.* Mr. President and gentlemen, my experience with this plant would not incline me to hold to the old-fashioned steam engine — for a small plant. It seems to me that the duty they are getting right along every day with a little over half load shows that the fuel cost of pumping water with a gas-producer plant is very much less than with a steam plant, — that

* Civil Engineer, Boston, Mass.

is, the kind of steam plants which we put in for a 1 000 000 gallon plant through New England.

If I were to put in another plant for myself for pumping water, or if I were to build a small electric power station, I should, I am sure, put in some kind of a producer gas plant. I know that neither Mr. Thomas or the officers of the Hingham Water Company would take that plant out and replace it by any such steam plant as is ordinarily put in for that purpose. Of course, if one had to install a 10 000 000 gallon plant or larger, one could get equally good results, equally high duty, from a steam plant, and perhaps might prefer to put in steam, that is, bearing the evils that we have, rather than flying to those we know not of. You will get the idea if I don't quote it just right. [Laughter.] I have had some experience with internal combustion motors for pumping water. We have two at Cohasset, and two at Scituate. They are small motors, the largest about 16 horse-power and, I think, too small for producer-gas plants. Our experience in both places has been very satisfactory as far as the cost of pumping is concerned, and that is what we are looking for.

I do not feel like discussing this thing because I hardly know what to say. If anybody wants to ask any questions, either Mr. Thomas or myself will try to answer them. [Applause.]

THE PRESIDENT. I should like to ask Mr. Gowing what he considers the limit of these gas-producer engines.

MR. GOWING. Which limit, up or down?

THE PRESIDENT. The limit as regards large size, I mean.

MR. GOWING. Oh, I don't know. If I were going to put in a pumping plant up to 100 or 200 horse-power, I think I should put in producer-gas, and probably divide it up into as many units as seemed best, so that in case of breakdown I would not be left without some power; in fact, for a 200 horse-power plant, I should like to have three 100 horse-power units and then I would be sure of having 200 horse-power all the time.

The upper limit I don't know much about. I understand that there are some very large producer-gas plants which are doing well.

I think producer-gas is used more in the territory west of the Hudson River than east of it. In regard to such things New England water-works men are a good deal like New England railroad

men; improvements in railroads usually start in the West and move East. This is a matter which is received with more favor in the West than here.

MR. FRANK A. BARBOUR.* In 1906 the town of St. Stephen, N. B., in connection with the new water supply, installed a gas producer plant exactly similar to that described by Mr. Thomas, but of a larger size. The installation included two producers, each of 135 horse-power nominal capacity, two engines of 125 horse-power nominal capacity, and two triplex double-acting power pumps which, running 32 revolutions per minute, have a capacity of 1 800 000 gallons each per twenty-four hours.

The fuel available in St. Stephen is Nova Scotia bituminous and American pea anthracite, obtainable at practically equal cost of about $5 per ton. The choice between a steam and gas-producer plant was made dependent on actual propositions on both types, bids being called for under the same general specification, with a requirement that bidders should guarantee a station duty, including banking and all standby losses, these to be determined by a three-day test with the engines running eight hours each day and banked the remaining sixteen hours. It was considered that a test of at least this length was necessary to get results of any value from the gas plant, and also that such a test would be the best practical expression of the actual commercial value of the plant. It is to be noted that the inclusion of the banking charge in the duty made the comparison more favorable to the gas producer, as the latter type of plant can be banked with but a small fraction of the fuel necessary for a steam plant of equal capacity.

Propositions were received from two builders of steam plants and from three builders of gas plants. The first cost of the steam plants ranged from 50 to 80 per cent. of that of the gas plants, but the guaranteed economy was also sufficiently lower to make the gas plant the more economical proposition. The work was awarded to the Olds Gas Power Company at a price, including producers, engines, pumps, and auxiliary apparatus, equal to about $100 per horse-power of engine, including the customs duty into Canada. As the engines are larger than necessary for the work of the pumps it may perhaps be reasonable to estimate the

* Civil Engineer, Boston, Mass.

cost per horse-power of such a plant at about $75 in New England.

The duty guaranteed was 115 000 000 foot-pounds per 100 pounds of pea anthracite coal, having a thermal value of 13 000 B. T. U., with not to exceed 10 per cent. ash nor 2 per cent. sulphur.

During the early days of trying out this plant the same troubles as described by Mr. Thomas were encountered, and a better description of the trials which any one will almost surely meet in getting acquainted with producer operation could not be presented. Unquestionably there are in this work more factors each of which may affect results and which demand consideration than with steam work. Any one can boil water without burning it, while relatively few men have any inherited knowledge of the processes necessary to the making of gas of a certain character. Operators for steam plants can easily be found who will readily make them go, whether economically or not being another question; while in producer work the apparatus must be handled about right in order to run at all, but if it goes it runs with good economy.

The difficulties encountered are usually confined to the producer end of the plant or in the making of the gas. The engine troubles, if any, are largely mechanical and readily corrected by the average mechanic. Because knowledge acquired by experiences such as those described by Mr. Thomas is necessary to the successful operation of such plants is no reason to conclude that the element of reliability is lacking. This Association is to be congratulated on the presentation of this valuable paper, but there is also a danger that incorrect inferences will be drawn from this frank statement of the troubles encountered in the early work, and attention should be called to the fact that, after the preliminary difficulties, the apparatus has worked with success and is to be duplicated in the enlargement of the plant. The experience at St. Stephen was very similar, as, after the early difficulties, the plant was left in the hands of a local engineer who is running it without any trouble, although previous to his acquaintance with this plant he had been engaged on steam work.

I think, further, it may perhaps be due to the builders of the plant to say that until the apparatus was in successful operation they did not expect it to be taken over by the town.

In the test at St. Stephen a duty of 125 000 000 foot-pounds per 100 pounds of coal fired, including banking and all standby losses, and with the water used in cooling and in compressing air for starting and blowing hot charged to the plant, was obtained. The coal was below the contract in thermal value, running about 12 000 B. T. U. per pound. The duty was, therefore, equivalent to 100 000-000 foot-pounds per 1 000 000 heat units.

The small amount of fuel used in banking the producer during the sixteen hours of idleness is notable. During the test this averaged 22 pounds for each generator, or equal to about 3 per cent. of the total coal, or about $\frac{1}{100}$ of a pound per hour of banking per nominal horse-power of generator. During another ten days' run the amount used in banking averaged 52 pounds or about 7 per cent. of the total coal used.

In the test, as in actual work, the ashes and coal lost in stoking from the door above the grate were screened and re-fired. The amount of material so screened depends on the operator, and experience in St. Stephen up to the present time decidedly indicates the economy of re-firing the salvage.

In actual running the plant has developed a station duty of somewhat over 120 000 000 foot-pounds per 100 pounds of coal, although the coal contains about 15 per cent. ash, and the engine is running at less than three-fourths of its nominal capacity. This approach to the test duty in every-day operation is worthy of note. Steam duties are usually based on ten-hour tests, and the average station duty, including banking, rarely exceeds 75 per cent. of the test duty. With producers there does not exist the same chance of running up the test duty by expert firing as in steam, and the result is a commercial economy more nearly equal to that found in the test.

The obtaining of pea anthracite coal best suited to the work is a matter to which considerable attention must be given by those operating this type of plant. The amount of incombustible material or ash in the coal does not seriously interfere with the operation of the generator, but it increases the labor in firing and in screening salvage. Sulphur, however, is an element to be strenuously avoided. As to the ash, it is difficult to obtain pea coal with less than 12 per cent. incombustible material. Analysis of

samples recently collected at twelve different collieries show an average ash of 13.63 per cent., with a minimum of 10.92 per cent., and a maximum of 20.65 per cent. In future contracts it would not be unreasonable to specify that the work shall be done with coal containing not more than 14 per cent. ash. Practically the user of producer plants must take commercial pea coal, as the mine agents will not sell according to specifications. If the coal is obtained from local wharves it usually contains, unless screened, so much sweepings and dirt, that the ash contents will run well over 15 per cent. If specially screened, it of course costs more than the average market price. The best way to obtain suitable coal is to buy direct from some colliery where the ash content is reasonably low and sulphur is known, by analysis, to be not present in dangerous amounts. The recent increased demand for small anthracite has resulted in an increased value of at least $1 per ton for this coal over the prices of a few years ago, and in future it will probably be well, in considering the relative economy of producer plants, to figure on a value of pea coal more nearly equal to that of the larger sizes of anthracite than it has been in the past.

In any particular problem of water-works pumping the choice of plant must rest on the relative cost of fuel, the size of the plant, and certain conditions in the method of distribution. Between the small sizes where heavy oil engines have a field and the larger sizes in which high class triple vertical steam engines are justifiable, the gas producer plant is certainly worthy of careful consideration. Its first cost will be more than that of a steam plant, its floor space practically the same, and its necessary attendance but little different. Its reliability, if properly constructed, is probably equal to steam. What may be the relative depreciation of a gas producer plant cannot perhaps be as yet predicated, but in every-day economy it greatly outclasses all but the highest grade of steam engines.

The President. Is there anything further to be said on this subject?

Mr. S. H. McKenzie. Mr. President, I might say for the information of those who come from the central part of Connecticut that in our town of Southington we have a 100 horse-power gas-producer plant which was recently installed by a drop forging concern. The manager took me in to see the plant the other day

and he couldn't say enough in praise of it; he said it was far superior to a 50 horse-power gasoline plant which he had been running, and I might say that it works beautifully.

The President. Have you any idea of the duty which the plant is developing?

Mr. McKenzie. I couldn't say.

Mr. A. O. Doane. I should like to ask how long it would take to start up, with the generator and everything cold, to blow up a fire and get it all started. I thought from what Mr. Thomas said it might take a long time to get the fire blown up and get the right quality of gas and everything, building a new fire.

Mr. Thomas. I am unable to answer the question in a manner that would be entirely satisfactory to Mr. Doane, for the reason that our needs have always allowed us to take plenty of time in starting our plant. I said in the course of my paper that we obtained a good test of gas at the generator after blowing the fire for an hour, and there is no reason why, as soon after this as a good test of gas is obtained at the engine, the plant should not be running. Please bear in mind that these conditions refer to starting up the plant after its having been shut down some time, with an absolutely fresh fire and everything cold. When starting up with a fire that has been banked over night we have, in our operating, had everything running in thirty minutes from the time the engineer arrived at the station, and in one or two instances this has been reduced to twenty minutes.

I trust no one will draw the conclusion from the paper that we are in any degree disappointed in our plant; on the contrary, we are altogether pleased. In considering what was best to incorporate in the paper, I selected experiences which should be accurate and interesting, and naturally enough these came during the first season. The operating from which material results was obtained came later and these were summed up in the closing pages of the paper, to which I again call your attention, and by carefully referring to these it will readily be seen what excellent service our plant is giving.

A FEW WORDS ABOUT HOLLOW CONCRETE-STEEL DAMS.

BY CHARLES H. EGLEE, HYDRAULIC ENGINEER, BOSTON.

[*December 11, 1907.*]

Mr. President and Gentlemen: I hardly think that the few words which I shall speak in relation to this subject should be dignified by the name of "paper," which implies that something has been specially prepared for the occasion. I feel a certain hesitancy in addressing this Association on this subject for several reasons, the first being that I am associated with a company whose business is the designing and the building of hollow concrete-steel dams. This is a very personal matter, and being, as you know, naturally of a shrinking and modest disposition [laughter], which has been, I might say, increased by a number of years' experience among you as a contractor [laughter], there is a natural delicacy in intruding upon you a subject with which I am so intimately and personally connected. Then, again, I hesitate because the company of which I have spoken has been very industriously engaged for the past few years in presenting to the public, through its literature, which has been very lavishly sent out all over the country, the principles of design and the methods of construction of this peculiar structure. Also, these methods and these designs have been the subject of a number of engineering and quasi-engineering articles that have appeared from time to time in the engineering papers under the form of paid advertisements.

I hardly know how to present to your mind's eye a picture of a modern hollow concrete and steel dam used for the impounding of water, or used for the creation of power on a stream. I presume that most of the members present are not particularly interested in power dams, but are more particularly interested in reservoir dams. I shall endeavor to draw, as well as words will permit me, a picture of a modern method of constructing for reservoir purposes a concrete-steel dam, such as is now being constructed by the city of Pittsfield.

Imagine, therefore, that the site of your dam has been cleared of brush, etc., and the foundation for the dam prepared, — just such a foundation as you would prepare for an ordinary earth and core-wall dam, the vegetable matter, mold, and muck being removed to reach a solid foundation. This, then, stretching at right angles to the stream across the valley, is ready for the reception of the dam. On this prepared surface is laid a flooring of concrete, not following the slopes of the ground, but being laid in horizontal planes and stepped up upon the slopes as we approach the summit or crest of the dam. Of course, as we step up, the concrete base is gradually narrowed until we reach the top.

This flooring of concrete is thoroughly interlaced with bars of steel. These bars of steel are computed of the proper size for resisting the pressure which will be brought to bear upon this foundation, and the concrete foundation is computed to be of a proper thickness to support the superstructure.

Imagine, then, that this floor has been spread. Upon the upstream side or heel of the dam a cut-off wall, corresponding to the ordinary core-wall, is sunk down through the loose strata until it reaches an impervious stratum, either of rock or of clay, so that the water will not pass underneath the wall. That is the ordinary core-wall construction in any ordinary dam, but in this dam it is placed upon the upstream side of the dam, — made of the best quality of concrete, thoroughly connected to the floor by means of steel reinforcing rods. On the lower or downstream side, at the front of the dam, there is another wall sunk, not to any considerable depth, but far enough so it secures between the walls all of the foundation earth material beneath the floor of the dam. This floor is pierced with holes, which are called "weep-holes," in order that if the cut-off wall should not thoroughly cut off the water, or if it should not be thoroughly connected with the underground and underwater impervious stratum, the water finds instant relief and comes up through these "weep-holes." Also, if there is a leak in the cut-off wall, these "weep-holes" will show where that leak is, and it may be repaired. That is the purpose of these "weep-holes," although I have never yet seen any of them weep.

Upon this floor there are erected piers, or what are technically termed "buttresses," which are the support of the dam proper.

These buttresses are erected parallel to the course of the stream, at right angles to the longest diameter of the floor, and rise from this floor up to the crest of the dam. In the instance of which I speak, at Pittsfield, they will be, at the highest point, 40 feet in height. These buttresses do not rise at the same width all the way up, but at every 10 feet of elevation they are stepped in and gradually narrowed until they come to the top. These buttresses are also reinforced with steel rods, and they are computed so that they shall be of such a size as will resist the crushing pressure of the water that is brought to bear upon the dam.

In the preparation of the floor, proper corrugations or steps are cut to receive these buttresses, and each one of them fits into its own particular place; and they are spaced from 10 feet apart to a somewhat larger space than that, as the structure requires. On the Pittsfield dam they are spaced 12 feet center to center. Upon a very soft foundation they would not be spaced so far apart; upon a rock foundation they might be spaced still farther apart. In one instance which I recall they are 18 feet apart, and in that instance the buttresses expand toward the water-bearing surface of the dam into "haunches," which receive the deck or the barrier proper to the water.

After these buttresses are in position a sheet of concrete is laid on the upstream side covering the buttresses all the way from the cut-off wall up to the top or crest of the dam. This sheet of concrete is thoroughly and completely interlaced with steel reinforcing rods and is made of the very best quality of concrete that is known at the present stage of the art. After this sheet of concrete or deck is laid from the bottom of the dam up to the top, the dam is complete.

You must not understand by this description, however, that all of these different processes are taken up consecutively, as I have explained them. In fact, all of these processes usually are going on at the same time. The excavation for the cut-off wall is progressing, behind that the floor is being laid, still further in the rear the first lift of the buttresses is being put up, and still further in the rear of that the deck is being spread on; so that the dam goes up, as it were, from the bottom to the top in a regular progressive order, and not in the order I have previously explained.

When this dam is completed, if you walk upstream to approach

PLATE I.

DAM AT CAIRO, NEW YORK.

the dam it has the appearance to you, more than anything else, of a series of gigantic horse stalls. (See Plate I.) The front of the dam being entirely open, you walk into the dam under the water. You walk over the floor until you have reached the deck of the dam. The dam is perfectly open to you, you can inspect it in any part, and as you stand there and look up to the height of 40 feet and then realize that between you and the water there is only a thickness of about 2 feet or 27 inches of concrete, and when you look at that concrete and see that it is perfectly dry and perfectly hard, you wonder why people haven't built that sort of a dam before, because it is so extremely simple.

I am not going at this time into any of the calculations or computations that are very carefully made in the designing of this dam; nor am I going to explain at this time why the buttresses are spaced as they are, or why the thickness of the deck should be what it is; but I am merely trying to give you in the few minutes allotted to me a description of such a dam which you can carry in your mind's eye.

This describes only a dam of the open-front storage type, but the principle is capable of so many different variations, and is so adaptable to almost every situation, that a very great length of time could be consumed in the explanation of all its peculiar features. Take, for instance, in this particular dam, the matter of an overflow or spillway. In about the center of the dam, over the bed of the brook, the buttresses on the front or downstream side of the dam are not shaped as are the majority of the buttresses, with a little incline toward the top, but they are shaped in a curve, an ogee curve, and that curve is overlaid with an apron of concrete in the same way that the deck is made. The crest is reduced a couple of feet in height at that point, and you have your overflow or spillway constructed which returns the overflow water directly into the old bed of the brook.

Elaborating that one particular feature, and carrying the apron all the way across the dam, you then have a dam that is entirely enclosed. It has the deck on the back, it has the apron on the front, and such a dam as that is put across a river where heavy logs are being driven, or where there is a large flow of ice when the stream breaks up in the springtime, and those logs, that water,

and that ice are returned to the bed of the stream over this apron which entirely encloses the lower part or front of the dam, the entire dam remaining open within. The fact that the dam is open at all times is a feature that is very commendable indeed, because that space can be utilized for so many different purposes. Take a dam like the Pittsfield dam, which is open at all times and easy of access, those spaces between the buttresses beneath the dam are used for the storage of tools or material. Within these spaces are the gate-chambers, the screens, the valves which control the flow of water to the city. They are all easy of access, and no special or particular gate-house is required. If the dam is used for power, as is the case of a dam in Maine, that part of the dam which is not used as a spillway or overflow for the water is enclosed in the front, there are different floors laid in the buttresses at different heights which are connected by iron stairways; the whole interior of the dam is warmed, is lighted by electricity, and these rooms are used for transformer rooms, for the storage of electrical material, for tools, for coal storage, for work shops, lathes are set up within them, and the whole operation of the maintenance of the dam, all the business that pertains to it, is carried on within the dam itself, even including the office of the works.

Another feature which is commendable in the openness of the interior of the dam is the fact that it is at all times accessible and open to inspection. There is no portion of a hollow concrete steel dam that cannot be visited at any time. We therefore know whether our dam is in good service, whether there are cracks or leaks in it, whether there are any repairs necessary, or whether there is any deterioration at any time. If those things should be discovered, they are very easily repaired; I don't know exactly how, because no repairs have yet been found necessary. But still it is a comfort to know that you can look at your dam inside and at any time you want to.

This interior space, too, in power developments, is frequently used for the installation of hydraulic and electric machinery. You take a dam that is from 50 to 100 feet in height — I recall two at the present time 70 feet in height — in which all of the machinery for the generation of electricity is contained under the roll-way,

under the crest of the dam. One of those dams is located in a very peculiar situation, in a box canyon in the West. There is no situation below the dam for a power house. The river is subject to extreme floods at times, cloud bursts, etc., and all the water that goes over the dam is concentrated into this narrow canyon. There is no place to put a power house, and if a power house could be put there the river would be constricted to such an extent that the house would be in danger of being washed away. Therefore, the whole apparatus is put within the dam itself, and all the water that goes over the spillway goes over the apparatus, excepting that which is carried into the dam for use in generating power. This dam is located so peculiarly that there is no opportunity even of getting the machinery into the power house until the dam is constructed. After the dam is finished and the pond filled, the machinery is floated down to the dam on bateaux and lifted up by derricks which are set in the rock and dropped down into the dam itself, and then installed. Probably no other dam could have been constructed in this peculiar situation, and it was necessary that a dam should be constructed there because there are extensive operations going on in that locality which require power, and coal is from $15 to $20 a ton.

The appearance of an open dam such as I have attempted to describe is best shown by Plate I. Here is a dam built for the generation of power, the two penstocks coming out through the bulkhead of the dam on the lefthand side of the picture, and the front of the buttresses showing that peculiar stall-like effect of which I spoke. When the water goes over the spillway of this dam, of course that effect is not visible. At the time this picture was made, the water was running through the dam, before the pond had been closed.

That brings me to another peculiar feature regarding these dams. As we build them in a river, we leave the lower part of the deck off of two or three or more of these spaces between the buttresses, and when we change our cofferdam and turn the river in the other direction, we permit the river to run through those spaces. You see that in this cut; the water is running through between certain of the buttresses; the lower part of the deck on the upstream side of the dam has not yet been put in place. Now, when the time

comes that we wish to fill this pond and permit the water to run over the top of the dam, those orifices must be closed. Formerly in the closing of a solid dam there were expensive works necessary, in the construction of cofferdams, etc., so that the concrete could be placed in security. But in this instance no such cofferdam is required. The orifices are fitted with grooves in the concrete at the back, and when we wish to close them up we merely construct a wooden gate and drop that gate, which is a series of stop-logs, into these grooves, and we shut the water off from running through the dam. Then we go inside the dam, and behind the shelter of these stop-logs we put in a drainage pipe which takes the water that will come through the little cracks of the logs and will carry that water away, and then within that security we build our forms and put in our concrete and permit the water to rise on the dam while we are doing it. Nothing will disturb the workmen, because they are inside under the shelter of the deck. We have all the opportunity we want, so far as time is concerned, and we can permit the concrete to remain there and set up just as long as ever it wants to, until it becomes as firm as all the rest of the dam is, thereby avoiding a very great deal of expense in cofferdamming and in pumping.

In fact this feature, further elaborated, permits us, as has been done in one or two instances, to build the entire dam all the way across the river on piers, without any cofferdam at all. This practice obtains, however, only when the river is of a moderate depth, one or two feet, and has a rock bottom. Under those circumstances caissons or piers are built and filled with concrete and brought up one after the other to above the level of the water, the river continuing to flow all the time. We have then a series of what appear to be stepping stones all the way across. Upon these stepping-stones scaffolds are erected and the superstructure of the dam is carried on, the river meantime continuing to flow underneath the dam. When the time comes to close these orifices, to stop the flow of the river, they are taken up one after the other, stop-logs are put down, and they are masoned up or concreted up from the inside.

The dam as it appears to you seems to be a very slight and skeleton-like structure as you approach it. The buttresses are

not very thick, about 2 feet, as I remember it, at the bottom, on this Pittsfield dam, which is 40 feet high; but as you approach nearer to it, get close to it, and within it, it has an entirely different effect upon you, particularly if you go within a dam that is entirely closed, both on the upstream and downstream side, having a complete deck and apron. The appearance of a massive structure under those conditions strikes you at once. It seems as though it was almost impossible that anything could occur that would affect the solidity and the permanence of that structure. It is necessary, however, very frequently that the permanence and stability of the structure should be well demonstrated in advance, before the structures are built. It will not do to say in many instances that this is so-and-so and it is so because I say so. That is a very bad attitude to assume when you are endeavoring to show to a person any new feature or any bold engineering, and *this is* bold engineering. Therefore the most minute and intimate calculations of all stresses and strains and compressions and pressures of all kinds are made upon each individual dam before anything is ever done in the perfection of its design. That is a feature that it is impossible to speak further of at this time. But there is one feature that is very frequently spoken of that ought to be brought to your attention, and that is the impermeability of the concrete which is used in the barrier to the water — the deck of the dam.

This deck is placed at an angle to the perpendicular, shown, in Fig. 1. This shows a full deck and apron dam, and is built on the Battenkill River. I want to speak to you about the angle that the deck presents to the water. That is the same principle that was used by our forefathers in the building of their old-fashioned wooden dams. There is nothing new about that. I believe that the beavers are still continuing to build that same kind of a dam. But the angle that the deck makes from the perpendicular is adjusted to each different problem as it is presented. This one shows that the angle of inclination from the perpendicular is about 45 degrees, or 1 to 1. Had that dam been built upon a soft bottom, requiring a floor, that angle from the perpendicular would have been greater, probably 52 or even 55 degrees, or an incline of 5 to 4, in order that there might be more pressure brought

in a perpendicular direction upon the foundation supporting the dam. It depends altogether upon what sort of a foundation is underneath a dam as to what the angle of the deck should be, and that is always the subject of very close computation. Also the thickness of the floor of a dam is computed to resist the pressures that are brought to bear upon it.

I have digressed somewhat from what I was going to speak about in relation to this deck, and that is the impermeability of the concrete which constitutes it. When this dam was first brought to my attention, and I looked into the designs, I said at

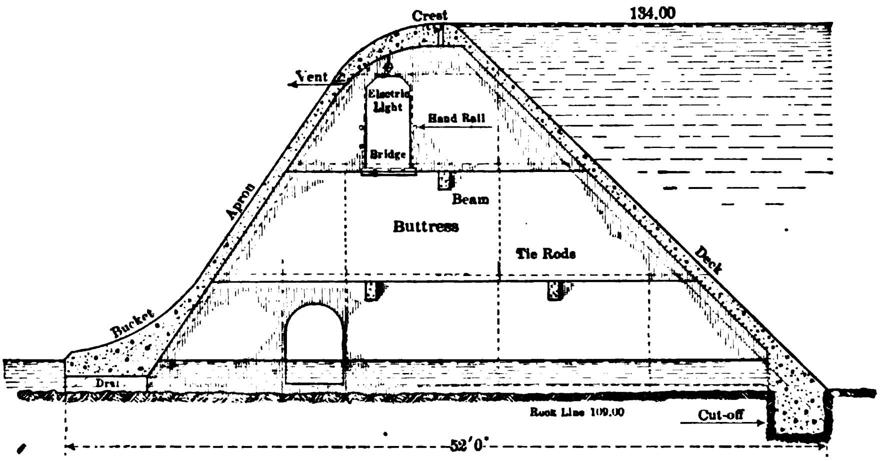


Fig. 1. Section of Hollow Concrete-Steel Dam.

once, "The whole thing is a failure; there is no necessity of going very much further into this thing because the deck will leak. Eighteen inches or two feet of concrete will not resist the pressure of water that is brought to bear upon it." And the representative of this company said to me, "How do you know?" "Well," I said, "in a modest way, for twenty-five years I have been putting in concrete; I have been putting in concrete as a contractor, to be sure, but sometimes we get in very good concrete. [Laughter.] In fact, some of the engineers with whom I have been employed have been very highly complimented on account of the concrete which I have put in. [Laughter.] And I know that two feet of concrete

is not enough. Why, the Metropolitan Water Board, when they wanted to hold 15 feet of water, put in a wall of concrete 7 feet thick, and then they weren't quite sure." Well, the president of this company said to me, " You remind me of that old story about the man in jail, whose lawyer told him they couldn't put him in jail for the offense for which he was committed; and the man said, ' Well, it don't make a particle of difference about that, I am *in*. ' " He didn't know how old the story was when he told it to me; if he had he wouldn't have told it; but it illustrated the case, because they *were* putting in the concrete, and I went and looked at it and it was a fact. And when I took my handkerchief out, in the interior of the dam, to wipe off the moisture from under side of the deck, it wiped off dust. There wasn't any moisture. That is a sure test. The concrete in the decks of hollow concrete-steel dams, well put in, mixed with fine aggregates, with plenty of cement and rather an overplus of water, more than is required for crystallization, — such a concrete as that will not leak.

Many have asked whether in the treatment of the deck of this dam there is any special preparation used. Nothing whatever is used. There isn't even a coat of plaster put on the water surface of the dam.

One great help, however, to the impermeability of concrete, which has lately been discussed, is the chemical action that takes place in concrete when exposed to water. The free lime in the cement is formed into carbonates by the action of the water in all the little minute voids which necessarily exist in any concrete, an action being set up exactly similar to the formation of stalactites in a limestone cave; and all these little minute voids are in time filled up with strong carbonates of lime. The water never penetrates beyond these, and this action is begun at the time that the water is brought in contact with the concrete surface and continues up to the time that all the voids are entirely filled. These carbonates of lime will not fill large voids. There must be no large voids in the concrete; the voids between the stones must be filled with the sand and with the cement, and the concrete when mixed must be mixed very wet. If you will notice in the mixing of concrete, where you use an overplus of water, the free water will run out from the forms, but it will not carry the cement with

it; it runs clear from the top, almost as clear as clear water; there is very little sediment. It is a strange thing how much water is required in the crystallization of concrete. There is very little, if any, absorption of moisture by the atmosphere. When you put concrete into a form and allow it to set, you take the form off and you find that the concrete is at the same level that it was when it was put in very wet. There has been no shrinking, at least no appreciable shrinking, although there is undoubtedly a slight shrinking which is carried on from that time until the concrete has got its formal and final set. It is perfectly wonderful how concrete put in in that manner, with due care and with fine aggregates, will resist the penetrating action of water brought to bear upon it under a pressure.

I was told I might speak just so long, and I find I have spoken two minutes over time. If there are any questions that may come to your minds in relation to this matter, for there are very many points upon which I have had no opportunity to touch, I should be very glad to endeavor to answer such question as you may wish to ask.

DISCUSSION.

THE PRESIDENT. Mr. Eglee inquired how long I wanted him to speak, and I asked him how long he could talk on the subject. He said two weeks. [Laughter.] I told him we would try 40 minutes. The subject is now open for discussion, and I think Mr. Eglee will be very glad to answer any question which may be asked.

MR. COGGESHALL. I should like to ask Mr. Eglee if it would be possible to build a reservoir on this principle.

MR. EGLEE. There has been a reservoir built in Waltham, lately, on the principle of a reinforced concrete-steel standpipe, 100 feet in diameter and 40 feet in height. I had the misfortune to build a standpipe of that character some few years ago, and when I finished it it was not tight, and it has never been tight since. There was one built for the city of Attleboro also. That, when built, was not tight, but the reasons for that were many and varied. They had nothing whatever to do with the concrete, which in both instances was of a very acceptable quality. In the instance that I cite, where I built a standpipe of that character, I believe that the problem was altogether too new in the mind of the contractor

and engineer, and it certainly was too new in my own mind, and I have always thought the fault was in the design. I believe that the fault in the Attleboro standpipe was more in the instability of the forms retaining the concrete than in anything else. They were permitted to slip once or twice.

We have designed several reservoirs, to be placed on an elevation, in which there was a floor laid, and on this floor a structure built exactly similar to the one I have been endeavoring to describe, — not round, but coming together at angles. I think the ones we designed were octagonal in shape. The principle was exactly the same. Let me say here, too, that the difficulties in the computations of a structure of that character are almost nothing compared with the difficulties of design of a regular standpipe. The difficulties of design and computation necessary in a dam of concrete-steel are as nothing as compared with the difficulties in computation and design of an ordinary concrete-steel building, which is put up every day.

MR. SULLIVAN. I am a little curious to find out what effect expansion and contraction has?

MR. EGLEE. I am very glad you have touched upon that point. The hollow concrete-steel dam is not a monolithic structure. It resembles, perhaps remotely, a house of cards. It does not fall down that way, but it is put up that way. Each buttress is divided at certain points; and the floor is divided at certain points; the deck is divided in horizontal spacings of 30 feet in small dams, and in large dams every bay (the space between the buttresses) is divided in construction. All these joints made throughout the dam are for the purpose of expansion and contraction. There is a movement in every dam; it does not make any difference how it is constructed, whether it be of masonry or of solid concrete or of concrete and steel, there is a movement due to expansion and contraction. I think if there was any one here from New Haven at the present time he would be able to give an instance of temperature cracks that have already appeared in the new solid concrete dam which was built there this season. The hollow dam, however, takes care of that expansion and contraction by these expansion joints which are left in the dam for that purpose.

MR. MCKENZIE. I understand that you do provide an expan-

sion joint in the decks once in 30 feet; that is, that the reinforcing rods do not cross that expansion joint, but are separated entirely at the ends.

Mr. Eglee. Yes, sir. If the buttresses are spaced, we will say, at 10 feet, then when the deck is put on it covers three buttresses and stops in the center of the third buttress. The next section of the deck covers 30 feet from that. There is no particular expansion joint made there; the work merely butts up to that and stops; the steel stops at that point, and there is a corrugation made, or a rabbet made, in the deck concrete at that point; and when the next section of the deck is put on the new concrete fills up the rabbet. That joint opens and closes. It is perceptible. If the concrete is laid in very hot weather, in the middle of the winter you can put your finger in the cracks.

Mr. McKenzie. You consider that 30 feet is the proper distance between the joints?

Mr. Eglee. It isn't always 30 feet; it depends on the thickness of the slab of concrete. In dams which are lower than 40 feet in height, we have determined that 30 feet is the proper distance for the expansion joints; at Pittsfield the distance is 25 feet, covering two buttresses.

Mr. McKenzie. I noticed in the New Haven filtration works, while there were no expansion joints, that once in about 14 to 18 feet it pulled open, even where the rods crossed, so that there was an opening of perhaps one sixteenth of an inch.

Mr. Eglee. That is very true. That pull is very perceptible. I can cite an instance of that in a certain dam in Vermont, where for some reason or other there were two steel rods which projected from one of the buttresses into the deck. There was an expansion joint which came upon that very buttress, and one of these rods was in the deck on one side of the expansion joint and the other rod was on the other side. The pull from contraction was strong enough to split the buttress vertically between the rods, and the deck opened just about as wide as my finger.

Mr. McKenzie. May I inquire also if you have not thickened up the concrete on the deck and on the apron from the original plans or from your practice of two or three years ago?

Mr. Eglee. Yes, sir. We have thickened the concrete on the

deck and the apron of the dam as a concession to public opinion. There is no necessity for a thickness of that kind, but it is very difficult to convince the building public that there is not such a necessity. We are also in such a position that we cannot make our buttresses as thin as the computation calls for. We put in a surplus quantity of material in the buttresses, but we save concrete by cutting out large openings in the buttresses.

MR. MCKENZIE. May I inquire if you have not also increased the thickness of the concrete outside of the reinforcing rods; that is, originally weren't they about 1 inch in from the outer surface, whereas now they are at a greater depth from the outer surface?

MR. EGLEE. That is caused by a difference in construction, merely. We want to put our reinforcing rods as near to the lower side of the deck as possible. The deck is computed as a beam which sustains a certain pressure. That beam rests from center to center of buttress. We therefore want to get our steel reinforcement as low into that beam as we possibly can; so we put our steel within one inch of the under surface. But a difference in construction has shown us that it is wise to drop our deck below the buttress and key it over the buttress a little bit. By doing that we obviate the necessity of building lateral beams between the buttresses. In dropping the under side of that deck 1 inch to give it that lap over the buttresses, it has made the steel 1 inch nearer to the water surface, and we have put 1 inch more concrete on on that account.

MR. MCKENZIE. What is the average depth from the surface of the concrete to the outer side of the rods in the deck and apron?

MR. EGLEE. That is a difficult question to answer. I can say that at the top, near the crest of the dam, usually the depth is 10 inches, unless the dam is in a river subject to heavy ice runs. In that case it is thickened considerably. In a water-works dam, like the reservoir dam at Pittsfield, I think the distance is 10 inches. The thickness increases all the way down to the bottom, depending upon the height of the dam.

MR. MCKENZIE. I had more particular reference to the matter of the penetration of the water and to the corrosion of the rods with respect to the depth that they were sunk in the concrete.

Mr. Eglee. I am glad you have brought up that question of corrosion of the rods. There is no corrosion of the rods. That has been demonstrated in various ways. In the first place, the rods are very close to the inner edge of the concrete. There is nothing shows more distinctly on concrete than rust. If water penetrated through that concrete and attacked those rods, the pressure of the water on the outside would force it through to the inside, and there would immediately be a stain of rust there. There is a stain of rust everywhere that we put a bolt through the concrete. We put bolts through the deck at the buttresses in order to hold our false work, our forms, and we set those bolts in a gas pipe in order that they may be removed. Every one of those gas pipes streaks the concrete with rust. It is not necessary to let the water rise; the very first rain will do that. If the water penetrated into the concrete and attacked those rods, we would know it immediately, because the rust would stain the inside.

Another proof that the rods are not attacked by the water is that there is no moisture on the inside of a dam excepting the moisture from condensation from the atmosphere. On a clear, crisp, dry, windy day there is no moisture on the inside of a dam; on a warm, muggy day there is always moisture dripping from the inside of the deck, caused by the coolness of the water on the outside.

Mr. D. E. Makepeace. I should like to state with regard to the standpipe in Attleboro, that it is absolutely tight and has been so for a long time.

Mr. Eglee. I beg to apologize, sir. I ought to have said that at the time of my last information, which was gathered at the time of the reading of the paper on the Attleboro standpipe, at the Annual Meeting at the White Mountains, the Attleboro standpipe, according to the statement in the paper there read, was not tight. And the reason which I have given for that, viz., some irregularity in the building of the forms, is what I gathered from the same paper. I am glad it is tight.

The President. Mr. Winslow, how is it about the Waltham standpipe?

Mr. Winslow. I don't know that Mr. Eglee said that that leaked.

Mr. Eglee. I think I should have said that the gentleman who built that standpipe informed me that it was absolutely and per-

fectly tight; that there never had been a repair of any character whatever upon it, and that it was a very satisfactory piece of work.

Mr. Richard A. Hale. I should like to ask Mr. Eglee if any special provision has been made in the form of the dam on large rivers like the Merrimac and Connecticut, where there is very heavy ice and where large quantities of logs frequently come down. Take it at high water in the Merrimac, ice is often two or three feet in thickness, and sometimes a boom of logs breaks away and comes down, and there is a great deal of trouble at the dam. I would like to ask whether special provision should not be made in the construction of a dam on such streams.

Mr. Eglee. Yes, sir. Special provision is made for the protection of the dam always. There is a dam built on the Missisquoi River, at Sheldon Springs, Vt. Before that dam was built, three dams had been carried away on that site within the previous seven years by ice gorges. The river there is very much constricted. The ice forms and comes down with a solid impact against the dam. To avoid that the deck of the dam is broken in its angle, and instead of going straight up from the bottom to the top like that, it goes up this way [illustrating], and then there is an easier slope which catches the ice and conveys it over the crest of the dam; and the same with logs. When the logs or the ice have gone over the crest of the dam, they are received by the apron and delivered upon a bucket. That bucket returns them to the river in as nearly a horizontal plane as can be computed. The ice and logs come down there very swiftly and heavily and strike on that bucket with force, unless there is a water cushion; therefore that bucket is made deeper and thicker and is very solid, computed to the necessities of the case.

I have spoken in my illustration of a dam 40 feet in height. When these dams were first being constructed it was presumed that when we reached a height of 25 or 30 feet we had reached the limit. Dams, however, are now under contract 100 and 150 feet in height on this same construction; and studies have lately been perfected for the government — which studies they do not expect to use, but they wish computations for — for this class of work under a head of 300 feet.

PROTECTING WATER PIPES FROM FREEZING.

[Topical Discussion, January 8, 1908.]

THE PRESIDENT. I want to ask some of the members to tell me what is a good, practically indestructible, cheap packing for water pipes over bridges. We have a case in Newton of a fairly long line of 16-inch main crossing a bridge, through which the flow is rather sluggish. If it wasn't so, we would probably leave the pipe as it is; but we are rather fearful that in severe weather the pipe may possibly get caught. We don't wish to use anything that is very expensive, and we don't wish to put in something which will rot out within a few years. I felt sure that I would get a suggestion from some of the members here to-day.

MR. R. C. P. COGGESHALL. I think I can say something, Mr. President. We have a bridge which connects our city with Fairhaven, which is located on the opposite side of our river. A few hundred feet from the New Bedford shore this bridge passes across a small island. The water between the New Bedford shore and this island was formerly the ship channel and here a draw in the bridge was located. Formerly, this island was supplied by a 2-inch lead pipe laid across the bottom of this channel. We had frequent trouble with it on account of freezing, which we attributed to anchor ice. This bridge was replaced by a new structure about five years ago, and as the draw was then located in another section, it was not necessary to longer continue the siphon to supply this island. Accordingly, a 6-inch pipe was laid upon a platform passage-way suspended from the bridge beneath the floor. This pipe was tightly covered with double boxing, with an air space between the two. This was done in 1902. We have had some severe winters since, but no trouble from that pipe. I thoroughly believe that a good "air space" is the best preventive of frost action.

MR. FRANK L. FULLER. Mr. President, I agree with Mr. Coggeshall. I have laid pipes over bridges in a great many instances, and double boxing has always been sufficient to prevent

the pipe from freezing. When we built the Wellesley works, we thought we would pack the pipe with tan-bark, but that soon became saturated with moisture and froze up solid, and I think that same winter, on account of the freezing of this mass of tan-bark around the pipe, the pipe also became frozen solid. I think we have had one or two cases where with double boxing and an air space the pipes have caught, but the pipes never have been frozen sufficiently to burst; and I think that where the circulation is at all good that is sufficient. In the place that is spoken of by the president, possibly still another boxing would be an additional protection. I am sure from my experience that an air space is much better than it is to put any substance around the pipes.

ONE YEAR'S PRACTICAL EVERYDAY EXPERIENCE WITH AN AUTOMOBILE FOR BUSINESS, BY A WATER-WORKS MAN.

BY F. F. FORBES, SUPERINTENDENT OF WATER WORKS, BROOKLINE, MASS.

[*Read January 8, 1908.*]

When, in December, 1906, it was proposed to procure an automobile for the use of the superintendent of the water department, the writer must confess that he had some misgivings as to the economic results which might be expected from the every-day use of such a machine.

One member of the water board in particular had had some experience with automobiles, and he was of the opinion that it would be for the benefit of the Water Department to own and operate an automobile, and his ideas in the matter received the hearty approval of the other members. The selection of a machine which would give the town the best service for a moderate outlay was not an easy problem to solve. After the usual preliminary work of looking over numerous catalogues and pamphlets gotten out by different manufacturers of automobiles, each one, of course, claiming that his machine was the best in the market, and personally examining different machines, the board decided to buy a 10 horse-power Cadillac runabout.

The price in Boston, including horn, lamps, and a few repair parts, was $794.00.

The results which have been obtained by one year's use of the automobile have been eminently satisfactory. It has been my custom to take the machine from the stable, where it was kept in the same building with the horses and wagons, every week-day morning and not return it to the stable necessarily until evening. If I spent one or more hours in the office, the machine was outside ready for immediate use.

At noon it was not necessary to feed it. The frequent calls here and there which all of us superintendents have could be made

in one half or perhaps one third the time required by a horse for motive power. I am very sure that two horses could not have done the work performed by our automobile during the busy months of the past season.

There is the further advantage that an automobile enables a superintendent to see more of the work under his charge and see it oftener, and also allows him more time for office duties. In fact, in my opinion, an automobile adds greatly to the efficiency of a superintendent.

An illustration of the time saved the writer on one day of each week can well be mentioned. On Monday it is one of the writer's duties to pay the men of the department, and he improves the time for an inspection of the pumping stations, the grounds around them, etc. The distance from the town hall is about seven miles — an hour's drive for a horse which is used every day, but an easy ride of twenty minutes with an auto, a saving of time in one half day of one hour and twenty minutes.

Perhaps some one will ask, How about all the delays caused by breakdowns, etc.? In reply I will say that in my opinion there is no more need of a breakdown or delay with an auto than there is when using a horse and wagon. During the whole of the past year, during which I have ridden over five thousand miles, I have not had one breakdown or delay of any account, and my automobile has never failed to bring me back to the stable on time with its own motive power at the close of the day's work.

It is particularly useful for night and Sunday calls. No horse to harness, but simply give a turn to the engine, jump into the automobile, and away at a speed of 20 or 30 miles per hour, provided, however, the police are not in sight, in which case a more moderate speed is advisable.

A few words in relation to the care of the machine and cost of maintenance may be of interest. Our stable man fills the tank with gasoline each day, usually in the morning, and sees that the oil and grease cups are full, and does the necessary washing. I have always made it a practice to examine the machine carefully once each day to see that the oiling devices are working properly and all the mechanical parts are in adjustment and repair. The tires will probably give one more trouble than anything else.

I always carry extra inner tubes in my automobile, as no one knows when a puncture may occur. I have been as long as three months without getting a puncture. The time required to replace an inner tube is about one-half hour, and after one knows how it is not a hard operation. The shoes, or tires, will last for a distance of from 3 000 to 5 000 miles, depending a good deal on the quality of the rubber in the shoes. I have worn out one set.

All must realize, however, that an automobile is a machine, and a rapidly running one at that, and consequently must receive the intelligent attention due all such mechanical devices. It is vitally important that all moving parts be kept well oiled and in good adjustment. For one who has some natural ideas of mechanics and is interested in mechanical matters this is not difficult or unpleasant and does not require much time.

The length of time required to learn to operate an automobile at slow speed need not be more than two or three days, but to feel as much at home behind the wheel at all speeds and in all places and act as mechanically as one does when walking, requires not less than four months of constant operating — at least, such has been my experience. It is a fact that one will learn little things about the machine nearly every day.

The maintenance of the automobile for twelve months has been as follows:

Repairs and extra parts	$58.18
Lubricating oil, 30 gallons	19.00
Gasoline, 330 gallons	71.15
Tires	113.40
Batteries and miscellaneous	9.68
Total	$271.41

In addition to the above expenses, it is necessary to have the machine carefully overhauled and painted once every year. This we find will cost from $75 to $100. The depreciation of the machine, supposing that at the end of four years its economic usefulness will end, will be $200 per year, making the total cost for one year $571.41. This amount gives a cost per day of $1.56.

It seems to the writer that, taking everything into consideration, it is greatly to the benefit of any water department, except

small ones, to use automobiles. The price per mile, about eleven cents, is less than the cost per mile when horses are used, and the saving in time is certainly an important item and in many cases worth more than the entire cost of operating the machine.

DISCUSSION.

Mr. Dexter Brackett.* I can say that the conditions on the Metropolitan Water Works are good, if not exceptional, for the use of automobiles to good advantage. From the limits of the Wachusett watershed in Princeton to the limits of the distribution system the distance is over seventy miles, and the distance across the district supplied with water is 20 miles. An inspection of the reservoirs and aqueducts, on account of the long distances, can be very greatly facilitated by the use of an automobile. I have used one on the work for four years, and there are now three machines of different makes in use on different parts of the works. Taking into consideration the saving in labor on account of the additional work which can be accomplished, there is, in my opinion, no doubt that they are a very valuable addition to almost any water-works plant.

As to the expense of operation, our experience has been that a light runabout operated almost constantly excepting during the winter can be expected to do good service for about three years at a cost of about $600 per annum, including first cost of the machine as well as repairs and supplies. The cost of repairs and supplies on the different machines has been from $200 to $450 per annum. As to the reliability of an automobile, much depends upon the care given to see that it is kept in good order. When I start on an all-day trip with a definite timetable I am very seldom delayed by the breaking down of the automobile. The only delay during the past season in riding between 4 000 and 5 000 miles, due to the automobile, was one of twenty minutes caused by a punctured tire.

Mr. Wm. F. Sullivan.† Mr. President, I agree with Mr. Forbes that the Cadillac is the best machine made, because I happen to have one this year. [Laughter.] In regard to breakdowns, we never had a breakdown; the only time it ever balked was when I

* Chief Engineer Metropolitan Water Works, Boston, Mass.
† Superintendent Pennichuck Water Company, Nashua, N. H.

had a hoodoo from this Association with me, a gentleman from the Builders' Iron Foundry. [Laughter.] The machine ran 2 300 miles to October 1, and it never failed to come back. We have never been "towed in." In addition to the usual work, our emergency man uses it for "hurry calls," and at night in answering alarms for fire.

We supposed that the overhauling was to be done by our engineer at the Pumping Station, but no such work has been necessary up to the present time. We reckon it is a great time saver because it gives us an opportunity to use the time usually consumed in going the rounds with a horse for other things.

I have here a few figures in regard to the cost of investment, and the economy of the automobile, that one of my friends wanted. The total cost of Cadillac (runabout) automobile, including top, lights, horn, gas tank, and 120-gallon Bowser gasoline storage tank and pump, was $1 084.98. For the maintenance of it last year we paid for gasoline, $25.14; cylinder oil, $4.35; grease, 20 cents; spindle oil, 30 cents; repairs on tires, $19.55; sundries, $1.65. The total expenditure was $51.19. Total mileage was 2 300. The cost per mile, $0.022. The mileage per gallon of gasoline, 17.7.

THE ACTION OF WATER ON PIPES.

BY FREELAND HOWE, JR., CHEMIST AND BACTERIOLOGIST, NORWAY, MAINE.

[*Read January 8, 1908.*]

It is the purpose of this paper to treat of the causes, extent, and results of, and the remedies for the action of water upon pipes. **Scope of Paper**

The subject is one of great importance and one which is not fully understood. Recent chemical research seems to throw new light upon the whole matter although the researches to which I refer present no really new theories, but furnish evidence substantiating principles which are clearly set forth in modern treatises on chemistry. The principal researches to which I refer are:

First. "The Corrosion of Iron," by Allerton S. Cushman, Washington, 1907. **New Light on Action**

Second. "The Corrosion of Iron and Steel," by Wm. H. Walker, *et als. Jour. Am. Chem. Soc.*, September, 1907.

Third. "Ionization of Water," by C. W. Kanolt. *Jour. Am. Chem. Soc.*, October, 1907.

As stated, the facts developed in these studies furnish confirmatory evidence to the principles of chemistry as given in modern works. In a trade publication which I wrote two years ago for the Pittsburg Filter Manufacturing Company, I ascribed the action of water on pipes to the same principles which these researches confirm.

Water pipes have been so extensively and seriously acted upon by the water which they convey as to cause the water to produce disease and death; water supplies to be abandoned and new ones sought; bursting of water pipes and failure of water pressure; complete replacement of considerable lengths of pipes; and to render the water unfit for drinking, washing, and various other purposes. The extent to which the action can go under certain circumstances is almost without limit and is dependent upon the **Extent and Result of Action**

conditions under which the action takes place. For these reasons the subject is one of great interest to all who are associated with water works.

There are important questions constantly arising as to what kinds of pipes are best adapted to certain kinds of water. Some waters affect a pipe of one quality while others do not. In many places nearly all metal pipes are seriously affected. The effect which water has upon pipes has been ascribed to various causes, *e.g.*, oxidation, abrasion, corrosion, tuberculation, electrolysis, action of carbonic acid, peroxide of hydrogen, biological activity, etc. There is a great medley of causes to which this action is referred. It is difficult to determine where one process leaves off and another begins. Is there one cause for this action or are there many? What is the exact truth regarding this action? To what extent will the action proceed? Is there any remedy or preventive? All these questions deserve serious consideration.

Problem Stated

For a solution of the problem it is necessary to know:

First, what *water* is; *second*, what *pipes* are; and *third*, what *action* is.

Dissociation

In order to arrive at a full understanding of the action of water on pipes, I consider it necessary to know what *dissociation* is. It is this: Water is made up of two atoms of hydrogen and one of oxygen. It is H_2O. There never has been, is not now, and probably never will be, any absolutely pure H_2O. Distilled water is an approximation to this, but distilled water dissociates slightly to form hydrogen ions (hydrion) and hydroxyl ions (hydroxidion); that is: $H_2O = H^{\cdot} + OH'$. This is dissociation, or one kind of it. Likewise all substances which go into solution in water dissociate to a greater or less extent, *i.e.*, split up into their component parts. Common salt (sodium chloride) dissociates to form its components, chlorine ions (chloridion) and sodium ions (sodion). The products of dissociation are termed *ions* and have properties different from the chemical elements from which they are derived. The dissociation of chemical substances is usually slight, and the weaker the solution the more complete the dissociation. Suppose we start with salt and water. If we put into the water more salt than will dissolve we have this combination, solid salt (sodium chloride), salt in solution, and dissociated salt giving rise to sodium

and chlorine ions (sodion and chloridion). The sodion is different from sodium, which is a metal, and the chloridion different from chlorine, which is a gas. The exact degree and manner of dissociation of all substances does not concern us here, but it does interest us to know that it is only when substances are dissociated into their component ions that they are most active chemically.

It happens that natural waters contain nearly all salts in such a low degree of concentration that they are completely dissociated or nearly so and hence are very active chemically. The quantity and quality of the ions determine to a large extent the action of the water on pipes.

Dissociation of Water

Kanolt, summarizing his own work and that of others working on the same subject before him, gives the following table showing the extent of the dissociation of water.

TABLE SHOWING THE HYDROGEN ION CONCENTRATION ($\times 10^7$) IN PURE WATER. RESULTS OF VARIOUS INVESTIGATIONS.

Investigator.	0°.	18°.	25°.
Arrhenius			1.1
Wijs			1.2
Nernst		0.8	
Löwenherz			1.19
Kohlrausch and Heydweiller	0.36	0.80	1.06
Kanolt	0.30	0.68	0.91

This means that at 0° one million liters contains 30 mg. of hydrogen ions and 510 mg. of hydroxyl ions; at 18°, 68 mg. of hydrogen ions and 116 mg. hydroxyl ions; at 25°, 91 mg. of hydrogen ions and 155 mg. hydroxyl ions. Without exception these quantities are smaller than those in which any elements of water are usually determined in making a sanitary or mineral analysis, and yet they are large enough to cause water to have a decided action toward metals. (*Cf.* Rept. St. Bd. Health, Mass., 1898.) Clark found that distilled water with exclusion of air dissolved 0.77 parts per million of lead in two weeks. Walker obtained similar results. I will defer the detailed interpretation till later. It is merely desired at this point to understand what dissociation is and to what extent it occurs in water — as pure as we can make it — distilled water. On account of its dissociation water can be regarded as either a weak acid or a weak base.

Carbon Dioxide

To a further understanding of the action of water on pipes I consider a detailed knowledge of "carbonic acid" of utmost importance. The chemical formula of carbonic acid is H_2CO_3, but no one has ever had this in his possession and probably never will, for it is, up to date, a hypothetical substance. It is merely a product of thought. Many chemists in the analysis of water determine the amount of "carbonic acid expressed as CO_2" (carbon dioxide). The Maine State Board of Health and Massachusetts State Board of Health do not consider the determination of this constituent of water of sufficient importance to record it in the regular analyses which they make of the public water supplies.

Method of Analysis

The determination for carbon dioxide is usually made by titrating 100 cc. of a freshly collected sample against fiftieth normal sodium carbonate, using phenolphthalein as an indicator. In this titration the reaction is as follows: In the first place the sodium carbonate dissociates or hydrolyzes so:

$$Na_2CO_3 + H_2O = 2Na^{\cdot} + 2OH' + CO_2,$$

which means that the sodium carbonate hydrolyzes to form sodion, hydroxidion, and carbon dioxide (a gas). Hydroxidion will form a chemical union with phenolphthalein to produce a compound which imparts to water a red color; but if the water happens to contain hydrion, this hydroxidion will unite with it to form water so:

$$OH' + H^{\cdot} = H_2O.$$

This reaction will take place as long as there is any hydrion left, when an excess of hydroxidion will remain and the pink color showing the end point will prevail.

The equation is usually written:

$$Na_2CO_3 + H_2CO_3 + H_2O = 2NaOH + H_2O + 2CO_2,$$

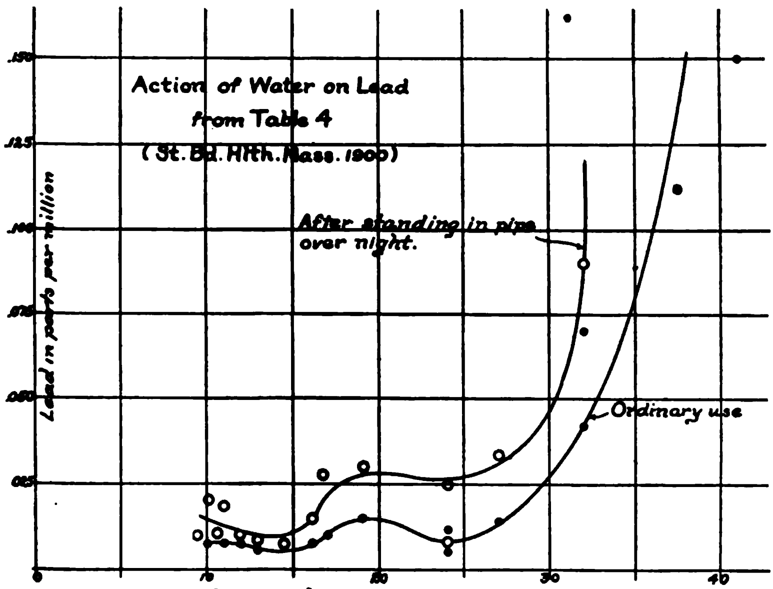
and the results are expressed as parts per million of CO_2. Usually the figures do show the exact number of parts of carbon dioxide present in the water, although this does not enter directly into the reaction by means of which its quantity is determined. The proper equation is:

$$2Na^{\cdot} + 2OH' + CO_2 + H^{\cdot} + HCO_3' = 2Na^{\cdot} + 2OH' + 2CO_2 + H_2O.$$

What actually happens is that the hydroxidion derived by hydrolysis from the sodium carbonate solution combines with the hydrion to form water. The hydrion is what gives water its acidity and it exists in the water by virtue of the presence of its partner (so to say), carbon dioxide. Its partner might as well be something else, in which case the analysis would erroneously show the presence of carbon dioxide.

The pressure of one atmosphere is fifteen pounds per square inch. Under this condition one liter of water will dissolve, at 60°, 580 mg. of CO_2. Under greater pressure water will dissolve more gas, the amount dissolved at any given number of atmospheres being about as many times as great as there are atmospheres pressure.

The accompanying diagram made from data contained in the 1898 report of the State Board of Health of Massachusetts shows that there is a direct correlation between the amount of carbonic acid present in water and the degree of action on lead pipe.



Significance of Analysis The new light in which I wish you to look at " carbon dioxide " is this: That while in the majority of cases there is present in a

water the same amount of carbon dioxide as the analysis indicates, the active principle which we determine in the water by analysis is the *hydrogen ion;* that this is what reacts with our chemical reagent, and that we merely assume the presence of the proper amount of CO_2 to allow the hydrion to be in the water. The correlation which the above diagram indicates is due, as we shall see later, to the action of the hydrion and not the CO_2.

Natural Occurrence

Almost every natural water contains some hydrogen ions, *i.e.*, is acid to phenolphthalein. Even rain water may be so. Surface water is still more so than rain water owing to the production of hydrogen ions and their complements in the soil and their extraction therefrom by the running water. Ground water is generally more acid to phenolphthalein than surface water for two principal reasons; first, that this water is longer in contact with the soil; and second, that being under more pressure, it can hold more hydrion and carbon dioxide.

Water a System

In arriving at an understanding of the action of water on pipes it is necessary to know what *water* is. My understanding of what water is may be a little different from that of some others. I understand water to be what chemists call a *system.*

A Chemical System

A chemical system is a collection of various elements or *components* which are each and all infinitely related to and dependent upon the others. The quantities of *some* components are dependent upon the quantities of others, and *some* cannot exist in the system unless others are there.

Different Systems

There are many different kinds of systems. Each is made up of an almost infinite number and kind of parts or elements, each and every one of which is dependent upon each and every other one. Each holds its place by virtue of the presence and deportment of all the rest. If one new element enters or leaves a system another one must come to or go from it in order to balance it. The natural tendency in every system is to maintain itself, *i.e.*, to preserve an equilibrium.

A Water System

I speak of *water* as a *system, i.e.*, H_2O, the carbonates, chlorine, magnesium, potassium, etc. Each element of the system is a *component.* As in the water-works system, so in the water system, a new element may enter naturally or artificially, and at the same time there leaves a certain other element or elements which results in the improvement or impoverishment of the system as applied to

man's various uses. These analogies might be carried indefinitely, but we have other considerations.

Let us now see of what a typical water system is composed, or what its components are.

Water Vapor

To this end we will start with water vapor which forms by evaporation from the surface of terrestrial bodies of water, from green leaves, etc. This vapor consists of hydrogen and oxygen and is invisible. It may become condensed and so visible in the form of clouds or fog. If condensed it consists of drops of water (H_2O) and in its passage through the air comes in contact with various substances for which it has a greater or less affinity. This water itself becomes dissociated, as before explained, both from the nature of the water itself and as a result of the action of ultra-violet light. This gives us, to start with:

$$2H_2O = H^{\cdot} + OH' \;+\; H_2O.$$

(hydrion, hydroxidion and water.)

This water comes in contact with carbon dioxide (CO_2), a gas present in air to the extent of about one volume in 2 500 of air. This would give us:

$$3H_2O + CO_2 = H_2O + H^{\cdot} + OH' + H^{\cdot} + \underbrace{HCO_3'}_{\text{hydrocarbanion, the new element}}.$$

Carbon dioxide gas is derived from various sources, among which are natural processes of decay, animal exhalations, and artificial combustion.

Other substances in the air which may become associated with our system are ammonia gas, nitric acid, oxygen, ozone, organic matter, dust particles (consisting of sea salt and many other light substances).

It has been found that 100 volumes of water under a pressure of one atmosphere will absorb the following volumes of gas:

	Oxygen.	Nitrogen.	Hydrogen.	Carbon dioxide.	Carbon monoxide.	Nitrous oxide.	Hydrogen sulphide.	Sulphur trioxide.	Marsh gas.	Ammonia.	Nitrogen trioxide.
0°	4.82	2.35	2.15	179.7	3.54	130.5	437.1	688.6	5.4	104960	7.38
20°	3.10	1.54	1.83	90.1	2.32	67.0	290.5	362.6	3.5	65400	4.71

As a result of contact with all these substances meteoric water may constitute a very complex system, as for example:

$$H_2O + 2H^{\cdot} + OH' + HCO_3' + Na^{\cdot} + Cl' + 3NH_3^{\cdot} + 2SO_4'' + Ca^{\cdot\cdot} + NO_3' + N + O_2, \text{ etc.}$$

Analyses of rain water show all these components present and to such an extent that the amount of solid matter obtained from rain water has been known to be as much as 50 gm. per cubic meter.

Surface Water

This water falling to the ground at once attaches to itself whatever substance it may come in contact with and which by its nature it may take up. Some of the elements already present may be precipitated in the soil or may be taken up by the various plants inhabiting the soil, such as molds, bacteria, mosses, ferns, grass, shrubs, trees, etc. Whatever changes do take place are very complex and it would take more than one lifetime to attempt to solve completely the exchange of elements which takes place here. As a general rule it may be said, however, that surface water contains more dissolved substances than meteoric water, although the reverse may be true.

Ground Water

A new factor which the water encounters in passing into the ground is pressure. Increased pressure allows the water to absorb more of certain elements than when it is under a pressure of only one atmosphere. Whether surface or ground water, the system comes in contact with more metals and salts and has its composition changed according to the geological and climatological conditions which pertain.

It is principally with surface and ground water that we are now interested, and the problems which confront us in studying the action of water upon pipes is wholly dependent on the character and quantity of the components of the system which this water forms.

What Pipes are

Having come to a knowledge of *what water is,* we will ask *what pipes are.* Pipes are of metal (more or less pure): iron, plain or zinc coated (galvanized), tin or lead lined; brass (copper and zinc); lead; block tin; copper; glass; wood; and cement or cement lined. Some pipes have internal and external coatings which prevent immediate contact of water and metal (more or less). These coatings may be imperfect on account of blow holes, scratches, etc. The metal of some pipes is impure, which might

cause galvanic action. Sometimes pipes of one metal are joined by means of another, which might also institute galvanic action.

Pipes then are mainly of metal, and in dealing with the action of water on pipes we have to do principally with the action of water on metals.

Potential Series of the Metals

By experimenting with different substances it has been found possible to arrange all the metals in what is called an *Electrochemical Series*, so that each precipitates all the metals following from their aqueous solutions and is in turn precipitated by each of the preceding ones. This series is also called the *Potential Series of the Metals* and is in part as follows:

Potassium	Cobalt
Sodium	Nickel
Calcium	Tin
Magnesium	Lead
Aluminum	Hydrogen
Manganese	Copper
Zinc	Silver
Iron	Platinum

Characteristics of the Metals

We have in this potential series of the elements an arrangement of the metals in the order in which they are dissolved in water in the greatest quantities and with the greatest energy, and, in a general way, a list of the metals in the opposite order of their degree of poisonous qualities. At one end of the series is sodium, which attacks water very violently, and at the other end is platinum, which chemists find almost indispensible in the laboratory because it is so resistant to all kinds of liquid. Zinc and iron occur in water in greatest quantity, but never enough, so far as known, to be poisonous, while the ions of lead, tin, copper, and silver are all poisonous.

If we have a system containing calcium, zinc, iron, and lead, metallic sodium will precipitate these from solution, *i.e.*, will replace them in the system. They will be converted into an insoluble form.

The metals throughout are characterized in that they receive only positive electrical charges; or they are able to go into solution only in the form of positive ions. The tendency which metals have of going into solution in this way is called the *Solution*

Pressure and has a definite value for each metal under definite conditions. In order to determine then in a definite way if any system of water with which we have to deal will act upon any of the metals of which pipes are composed, it is necessary to know the nature of the metals and also the nature of the system. A shorter way is to put the two together and determine by analysis if action does take place. But sometimes this is an expensive operation, and even then we are not sure whether the action, if present, will be permanent. It is desirable to have as complete a knowledge as possible of all conditions.

Mode of Action

Metals replace Hydrion

How, now, do different waters act upon the metals of pipes? We have seen that hydrogen ions are almost universally present in natural waters and even in distilled water, and we also observe that hydrogen has a place in the potential series of the metals which would allow it to be replaced by nearly all of the metals of which pipes are made, viz., zinc, iron, tin, and lead; and this is exactly what does take place in almost all cases where pipes are acted upon. When hydrion is present in water under proper conditions it will be displaced by any of the metals named and will itself become converted into inactive gaseous hydrogen and escape from the water if possible.

Copper

Copper occurs in the series after hydrogen, which would lead us to suppose that it cannot replace hydrogen. This is true and shows the reason why copper is particularly adapted for water conductors.

Silver

Silver occupies a position in the series which makes it affected still less than copper. This fact is taken advantage of in some cases, *e.g.*, at Poland Springs, Maine, where a silver-lined pump and connections are being built for use in connection with Hiram Ricker & Sons' beautiful bottling establishment.

The following table is prepared from the records of the Massachusetts State Board of Health. It shows that different waters, each acting under the same conditions, affect zinc most, iron next, and lead and tin least. The figures show averages:

PARTS PER MILLION DISSOLVED.

	Zinc.	Iron.	Lead.	Tin.
Fairhaven	9.7	4.7	2.0	0.2
Kingston	4.5	0.05	2.5	0.19
Lowell	5.6		0.4	0.09
New Bedford	5.1	1.9	1.6	0.25
(Time of action, one hour)				
Fairhaven	15.4	9.2	4.0	0.4
(Time of action, over night)				

In the case of zinc and iron, the difference is plain; but there seems to be less tin than lead dissolved, a fact which is of general prevalence. The reason probably is that tin does not form powerful bases; that at ordinary temperatures it does not oxidize, while lead oxidizes easily at low temperatures. Zinc, which is the pipe metal farthest removed from hydrogen, acts most strongly, and iron next. Lead and tin are close together, near hydrogen, and have a less solvent action. Lead oxide is slightly soluble in water and communicates an alkaline reaction to it since it forms hydroxidion.

Apparent Exceptions

That copper is not acted upon by natural waters like other metals is due to two things: *first*, its place in the potential series of the metals; and *second*, that in many natural waters a protective coating is rapidly formed over the surface. That metallic copper does react with water has been demonstrated in the case of the investigations in relation to the sterilization of waters, but here it does not act like other metals. A reduction product of some anion present in the water is formed something like: **Copper**

$$3Cu + 8H^{\cdot} + 8NO_3' = {}_3Cu^{\cdot\cdot} + 6NO_3' + 2NO + 4H_2O;$$

$$\text{or, } Cu + 4H^{\cdot} + 2SO_4'' = Cu^{\cdot\cdot} + SO_4'' + SO_2 + 2H_2O.$$

Another apparent exception to the statements herein made is in the case where a water containing an excess of lime, and, therefore, no hydrion, has a decided solvent action on lead pipes, a condition which Fuller reports during the experimental work at Cincinnati. In this case also the lead probably goes into solution as part of an anion which, on concentration, would form a plumbate in the same way that aluminum with sodium hydroxide forms an aluminate. **Lead**

$$Pb + Ca^{\cdot\cdot} + 2OH' = Ca^{\cdot\cdot} + PbO_2'' + H_2.$$

This of course is an artificial condition and one not often met with except in the case of softening or " lime and iron " plants.

Mr. Fuller does not explain the reaction nor does he state how the lead went into solution, but in all probability it was as an anion as stated, either PbO_2'' or $HPbO_2'$.

Role of Oxygen Thus far in my discussion I have not alluded to the action of oxygen, which is generally considered the all-important factor in the action of water on pipes. Walker *et als.*, in their study on the Corrosion of Iron and Steel, concluded among other things that the primary function of oxygen in the corrosion of iron is in depolarizing those cathodic portions of the iron upon which the hydrogen tends to precipitate and that it acts only secondarily to oxidize ferrous to ferric iron. This means that in the absence of oxygen (an extremely unnatural condition) there would be a tendency to polarization in a quiet water which would act as a preventive to the further formation of hydrogen gas and a concomitant retardation to the solution of a metal. Without doubt the low degree of action which Clark found when lead was placed in distilled water with exclusion of air was due to the same cause.

Electrolysis In the case of electrolysis of pipes the metal is dissolved in exactly the way described above, but the action is accelerated by the action of the electric current which tends to drive the metals into solution at the point or points where the current leaves the pipe to enter the water — whether inside the pipe or out. Investigations are under way to determine the extent of corrosion of pipes in moist soils so that we may know how much of the corrosion is natural (so to say) and how much induced by the action of stray currents from electric railways, etc.

Conditions affecting Solution of Metals Other conditions which tend to increase or retard the action of water on pipes are temperature, pressure, concentration of salts, amount of organic matter, etc. Increase in any of these factors tends to increase the action of water on pipes except in such cases as where the salts in solution unite with the metals to form insoluble compounds which deposit on the pipes to form coatings through which the water cannot act. Such coatings form chiefly on lead and copper pipes and are very effectual in preventing the solution of the metal of the pipe.

Forms of Action The explanations given above embrace practically all forms of action which water has upon pipes. This action is described under various names: corrosion or eating away; pitting, formation of

depressions; electrolysis, decomposition of a pipe by an electrical current; tuberculation, action accompanied by the formation of tubercules or limpets. All phenomena are due to one principal cause, — the solution of the metal. In all cases the metal replaces something in the water.

It matters not whether a pipe is laid through a stream (surrounded by water) or in moist soil; whether water passes through the pipe or outside of it. If the metal is exposed inside or out and the proper conditions prevail, action will result.

Aside from mechanical abrasion the method of action explains all natural and some artificial occurrences. The metal of the pipe, by virtue of its solution pressure, replaces the hydrogen ion occurring naturally in the water, and the hydrogen gas so formed escapes to the atmosphere if possible.

Remedial Measures

Now that we have taken so much time in arriving at an understanding of the action of water upon pipes, what does it all amount to? It amounts to this: that understanding what the elements concerned in the action are, and knowing what their properties are, we are so able to treat the water that their effect may be overcome. In one particular case I was the fifth chemist called in by a water company to determine their trouble. Every other one had pronounced the water of exceptional purity, but even then the water company were not able to make the consumers believe so. At the source the supply was of " exceptional purity," but the water had a powerful solvent action on iron pipes so that by the time it reached the consumers it not only contained large amounts of iron but had a very offensive odor and taste. An inexpensive method of removing the dissolving substance was found and the effect was so pronounced that the very next day after starting the apparatus every one in town remarked about the improved conditions and the water is now giving general satisfaction. Not one of the chemists preceding me had made a determination for even the presence of the element by virtue of which the water affected the pipes.

Knowing what the offending impurities in any water are, it is comparatively easy to know how they get there and so how to get them out. The case just cited was handled in the manner outlined above.

It is impossible to outline any method of procedure which will

furnish relief in all cases as no two are exactly alike, but in general it can be said that in most cases a simple aëration will accomplish remarkable results.

DISCUSSION.

THE PRESIDENT. This paper is now open for discussion.

MR. B. B. HODGMAN. Mr. President, I should like to ask Mr. Howe if it is the hydrogen ions that affect the iron.

MR. HOWE. The hydrogen ions, under proper conditions, are replaced by the iron metal of the pipe, in the case of an iron pipe.

MR. HODGMAN. Are the hydrogen ions found in waters which are very alkaline?

MR. HOWE. They occur in nearly all natural waters, even very alkaline waters.

MR. E. D. ELDREDGE. I would like to ask Mr. Howe if there is more rust on the pipes in summer — in high temperature — than in low temperature; if rust is present in greater quantities at one time of the year than another.

MR. HOWE. Usually in summer there is more carbon dioxide formed, the carbon dioxide being formed by the decomposition of vegetable matter, so that there is more of it to go into solution. But, on the other hand, the increased temperature will drive it from solution; just the same as when you boil water in a teakettle, or in any open vessel, the boiling process liberates all the carbon dioxide and with it the hydrogen ions which accompany it. That is the reason that boiled water is so much softer than water not boiled, — because the carbon dioxide and the accompanying hydrogen ion — or metal which has replaced it — is removed by the boiling process.

Briefly, in answer to your question, there is more carbon dioxide in summer to be dissolved, but the higher temperature will allow the solution of less. So the action in winter would be greater, because the decreased temperature allows more carbon dioxide, and the accompanying hydrogen ion, to go into solution, and so act upon the pipe.

MR. A. O. DOANE. I have noticed that hot water has a much more corrosive action upon pipes than cold water; hot water meters are very difficult to maintain. Now, I should like to ask

Mr. Howe to explain the more corrosive action of the hot water than the same water when it is cold.

Mr. Howe. Mr. President, it is almost impossible to discuss the subject upon general principles, because waters are so different; but in the presence of certain salts there would be a formation of hydrogen ions induced by heat which would not occur in other waters. That would be the case particularly in hard waters containing magnesia.

Mr. Doane. The particular case I had reference to was water in the Metropolitan District, which is not considered hard water, although I think almost all hot waters do affect the composition parts of meters more than cold waters.

Mr. Howe. Under heat the action of water is much greater than it is when water is cold. In a boiler the water is confined, so that these elements which affect the metals are not allowed to escape; and the action would be greater if the water were confined, as in a boiler, and also the pressure would increase the action.

Mr. G. E. Winslow. Mr. President, there have been a great many cases of lead poisoning from the water going through lead pipes; in the city of Waltham the pipes connecting the services with the mains are perhaps 18 or 20 inches long; I had occasion to take out a great many of them in years gone by, and in all cases I found them of a bright color inside. I would like to know what is the nature of the action of the water on that lead which might cause lead poisoning.

Mr. Howe. In answer to the gentleman's question I will say that in waters which naturally contain one grain per gallon of substances determined as carbonates, there is usually formed a coating over the lead which prevents further action of the water upon the pipe. In the case of distilled water, Mr. Clark found, in his work, "The Action of Water upon Metals," that a very much larger amount of lead was dissolved by distilled water than by water which contained a small quantity of dissolved salts. And the reason for that is, as stated, that a portion of the salts combines with the lead to form an insoluble lead salt, which joins with the lead pipe and prevents further action by the water. The lead is protected to a considerable extent by the formation of this insoluble lead salt on the pipe.

MR. S. H. MCKENZIE. I should like to inquire if an ordinary soft surface water would contain more than that one grain per gallon of carbonate just spoken of.

MR. HOWE. Some waters, Mr. President, contain much less than one grain per gallon, or 17 parts per million, particularly in our granite regions of New England; but usually nearly all waters contain that much; there are exceptions, however.

MR. MCKENZIE. If the water contained less than one grain of carbonate per gallon, would it be detrimental to the consumer?

MR. HOWE. In general terms, yes, that water would have an action upon lead pipe.

MR. MCKENZIE. If, in removing the goose neck, you find a sort of slimy coating upon the inside, would you say that lead had been coated over?

MR. HOWE. This coating usually has considerable substance to it; the carbonate usually has more consistency. The slimy coating might be something else, or else it might be hydroxide. It would be impossible to tell without examination.

MR. E. B. PHELPS. Mr. President, there is one aspect of this question which Mr. Howe just alluded to; that is, the possibility of action where two metals are coupled up in the same pipe system. I have recently been in the middle West, where there is an alkaline water which, according to Mr. Howe's theories, ought not to have great solvent action, but this water has very serious solvent action upon galvanized iron pipe, and the trouble is traced to the very common use of brass pipe in the faucets.

THE PRESIDENT. Is there anything further to be said?

MR. FULLER. I should like to ask Mr. Howe for just a word with regard to the use of galvanized iron pipe for service pipes, or for use in houses, as to their desirability for conveying water.

MR. HOWE. It depends entirely upon the composition of the water.

MR. FULLER. Take a ground water, Mr. Howe, for instance.

MR. HOWE. Ground water affects all pipes, generally, more than surface water; of course it contains more of this active element. In other ways it would affect the pipes less, on account of the presence of more salts which would exist to form protective coatings. An exact knowledge of a definite place must be had in order to pass definite judgment.

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, January 8, 1908.

The President, Mr. John C. Whitney, in the chair.
The following members and guests were present:

Honorary Member.

F. W. Shepperd. — 1.

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, G. W. Batchelder, J. E. Beals, A. F. Ballou, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, James Burnie, George Cassell, J. C. Chase, C. E. Childs, H. W. Clark, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, J. W. Crawford, J. H. Child, A. W. Cuddeback, L. E. Daboll, A. O. Doane, E. D. Eldredge, I. T. Farnham, J. H. Flynn, F. F. Forbes, W. E. Foss, A. N. French, F. L. Fuller, H. M. Geer, J. A. Gould, F. J. Gifford, R. A. Hale, F. E. Hall, T. G. Hazard, Jr., D. A. Heffernan, B. B. Hodgman, H. G. Holden, Freeland Howe, Jr., C. L. Howes, W. S. Johnson, J. W. Kay, Willard Kent, F. C. Kimball, G. A. King, E. S. Larned, S. H. McKenzie, Thomas McKenzie, N. A. McMillen, A. E. Martin, John Mayo, J. F. Moore, C. A. Mixer, O. E. Parks, W. W. Patch, H. E. Royce, H. W. Sanderson, P. R. Sanders, E. M. Shedd, C. W. Sherman, J. Waldo Smith, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, W. M. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, C. A. Townsend, W. H. Vaughn, J. C. Whitney, L. J. Wilber, F. B. Wilkins, H. B. Wood. — 79.

Associates.

Anderson Coupling Company, by Charles E. Pratt and F. A. Leavitt; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edward F. Hughes; The Fairbanks Company, by George H. Gray; Hersey Manufacturing Company, by Walter A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve

Manufacturing Company by, H. F. Gould; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; NationalWater Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by Fred A. Smith and H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Platts Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown and F. S. Bates; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Chas. Millar & Son Company, by Charles F. Glavin; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle; R. D. Wood & Co., by W. F. Woodburn, Harry Crowther, and H. A. Jensennius. — 28.

GUESTS.

James G. Hill, water commissioner, Dr. T. T. Carroll, Lowell, Mass.; L. R. Washburn and William E.Smith, members Water Board, New Bedford, Mass.; A. E. Blackmer, superintendent water works, Plymouth, Mass.; Joseph Weeks, Bridgewater, Mass.; Horace Mitchell, Kittery Point, Me.; J. J. Ryan, foreman water works, Southington, Conn.; D. W. McCormo, Panama; Mr. A. C. Horn, New York City; L. H. Camfel and Charles R. Gow, Boston, Mass. — 12.

At the close of the dinner the meeting was called to order by President Whitney, who said:

PRESIDENT'S ADDRESS.

Gentlemen of the New England Water Works Association, — Again we meet to review briefly the work of the year just passed, the twenty-fifth in the history of our Association.

Since the last report we have to record the death of six members:

Lewis P. Collins, ex-mayor of Lawrence, Mass., elected a member December 12, 1894.

Myron Edward Evans, C. E., New York City, president of the Cape Breton Railway, elected a member June 13, 1900.

Valentine C. Hastings, superintendent of the Concord, N. H., water works, a member since June 10, 1886.

Arthur J. L. Loretz, M. E., New York City, elected to membership December 9, 1896.

James W. Locke, general foreman water works, Brockton, Mass., a member since January 9, 1895.

John F. J. Mulhall, Boston, Mass., water-works accountant and treasurer of several water companies, elected to membership November 14, 1900.

Mr. Hastings had served on various committees, had twice been vice-president, took an active interest in the Association, and his loss was deeply felt. He had been superintendent at Concord, N. H., for thirty-four years.

Our total membership is now 702, a gain for the year of 18. It should, perhaps, be emphasized that this membership is absolutely net, all whose assessments were overdue having been dropped from the rolls.

The rate of growth seems fairly satisfactory until we attempt to analyze our membership, when we discover that over 40 per cent. of New England municipalities having a population in excess of 3 000 are not represented in this Association.

These figures open before our vision a broad, fruitful field for missionary work; we know that membership in our Association would benefit every one of these outsiders; we believe that each one would bring something of value to our meetings.

The first president of our Association in his address recommended that each city and town assume the expense incurred in attending these meetings, as the knowledge obtained was of direct benefit to the municipality, and it may further be said that the water-works official who is neither a member of this Association nor a subscriber to the JOURNAL is handicapped in the administration of his plant.

We are to be congratulated on our financial condition. After paying all bills there is a treasury balance of over $4 000, a substantial increase over 1906, and more than double the amount possessed by the Association six years ago.

The JOURNAL, of which we all are proud, speaks for the intelligent, discriminating work of the Editor. Particular mention should be made of the water-works statistics printed in the September number. It is but a simple statement of fact to say that this invaluable publication is still improving.

Mr. Sherman has also brought up to date a table appearing first in 1902, and which at this time is of special interest as showing, with other information, the progress of the Association during the twenty-five years of its existence.

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	702	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30

* Deceased. † Not including December JOURNAL and reprints.

The usual winter meetings have been held and were well attended; papers proved interesting and were thoroughly discussed.

Special mention should be made of the paper by Mr. William S. Johnson given at the March meeting, "Some New Facts Relating to the Effect of Meters on the Consumption of Water." His view of the subject was from a somewhat unusual standpoint and brought out so full a discussion that the paper, with accompanying comments, filled the June number of the JOURNAL.

In June we had a trip to Gloucester, going by steamer and returning by train, with a shore dinner in Gloucester and a trolley trip "around the Cape."

The annual convention at Springfield in September was a success in every way. Attendance was large, papers interesting, hotel accommodations satisfactory, a well-managed exhibition of water-works appliances, and on the last day a visit to the Springfield filtration plant at Ludlow, and, through the courtesy of the Chapman Valve Manufacturing Company, an opportunity to inspect their works and to partake of luncheon which they kindly provided.

At Springfield, largely due to papers read on "Water Rights" and "Value of Water Powers," with the discussion which followed, it was

Voted: "That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association or other organization of mill owners, leading to the formulating of standard rules and methods of computing or assessing damages for the diversion of water."

At the November meeting a committee of five was appointed to compile information relating to awards that have been made in water-works valuation cases.

At the same session a committee of five was appointed to prepare a standard specification for fire hydrants.

Three able committees have been appointed to consider these important subjects, and their findings, when presented, will prove of the greatest value.

Reports of the Secretary, Treasurer, Editor, and Auditing Com-

mittee will show in detail the standing of the Association as compared with that of a year ago.

We appreciate fully the good work of these officers, not forgetting the painstaking service of the Assistant Secretary.

I thank you for your support and consideration the past year, and let us bear in mind that the New England Water Works Association can move onward and upward only by the hearty coöperation of every member.

Report of Secretary.

Mr. President and Members of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts and disbursements of the New England Water Works Association for the year ending December 31, 1907:

Membership.

The total membership of the Association of all grades Dec. 31, 1906, was	684
" " " " " " " " " " " 1907, "	702
A net increase during the year of	18

The increase being in the grade of member, the list of honorary members remaining the same as last year, and the changes in the associate grade resulting in the present number of associates being the same as on December 31, 1906.

The present membership is divided among the different grades as follows:

Members	636
Honorary members	15
Associates	51
A total of	702

The detail of changes in membership is as follows:

Membership.

The total membership of the Association January 1, 1907, was	618
The present membership is	636
A net increase during the year of	18

Members.

January 1, 1907.	Total members		618	
	Withdrawals:			
	Resigned	13		
	Died	6		
	Dropped	32	51	567

	Initiations:			
	January	4		
	February	5		
	March	10		
	September	19		
	November	5		
	December	4	47	
	Seven members elected in 1906 but qualified in 1907		7	54
	Reinstated:			
	Members dropped in 1906		6	
	Members dropped in 1907		9	15	636

HONORARY MEMBERS.

January 1, 1907.	Honorary members	15		
January 1, 1908.	Honorary members			15

ASSOCIATES.

January 1, 1907.	Total associates		51	
	Withdrawals:			
	Resigned	2		
	Died	1	3	
			48	
	Initiations:			
	September	2		
	December	1	3	51
January 1, 1908.	Total membership			702

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1907.

RECEIPTS.

Initiation Fees			$256.00
Annual Dues:			
Members	$1 881.00		
Associates	750.00	$2 631.00	
Fractional dues:			
Members	$29.00		
Associates	15.00	44.00	
Past dues		29.35	
Total dues			2 704.35

Advertisements	$1 728.75
Subscriptions	167.75
JOURNALS sold	256.17
Sundries	42.30
Excess of receipts over expenditures June 26, 1907 (June Excursion)	23.78
Total receipts	$5 179.10

DISBURSEMENTS.

JOURNAL	$1 137.47
Assistant Secretary	600.00
Stationery and printing	400.49
Rent	400.00
Advertising Agent	306.00
Editor	300.00
Secretary	200.00
Stenographer	195.25
Incidental expenses	184.20
Membership list	150.50
Reprints	101.50
Music	80.00
Stereopticon	70.40
Treasurer	50.00
Badges	45.50
Insurance	15.00
Library	5.50
Total disbursements	$4 241.81*
Receipts in excess of expenditures	$937.29

At present there is due the Association:

For advertisements	$280.00
For initation fee and dues	14.00
For JOURNALS	5.00
For subscriptions	3.00
For Standard Specifications	.80
Total	$302.80

I know of no outstanding bills against the Association except those for the December issue of the JOURNAL not yet received.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion duly seconded the report of the Secretary was accepted and placed on file.

* Note that this differs slightly from the Treasurer's statement since it includes two small bills which have been lost in the mails and are not yet paid.

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.

1907.					
Jan.	5	Balance on hand			$3 410.53
Aug.	1	Dividends, Peoples Savings Bank, Worcester			62.98
Dec.	7	Dividends, Mechanics Savings Bank, Reading			49.75
Feb.	4	Rec'd of Willard Kent, Sec'y,	$1 427.90		
March	6	" " " "	692.95		
May	8	" " " "	656.45		
July	10	" " " "	651.20		
July	23	" " " "	160.28		
Oct.	23	" " " "	775.20		
Dec.	6	" " " "	404.15		
1908.					
Jan.	3	" " " "	410.97		
				5 179.10	
					$8 702.36

EXPENDITURES.

Paid bills, as per itemized statement		$4 222.06
BALANCE ON HAND.		
Deposit Peoples Savings Bank, Worcester	$1 600.00	
Deposit Mechanics Savings Bank, Reading	1 202.95	
Deposit First National Bank, Reading	1 273.20	
Deposit Liberty Trust Company, Boston	404.15	
		4 480.30
		$8 702.36

READING, MASS., January 6, 1908.

LEWIS M. BANCROFT, *Treasurer*.

DETAILED STATEMENT OF BILLS PAID.

1907.		
January 15	Emerson H. Packard, music, January 9	$10.00
	Hub Engraving Company, plates	7.61
19	L. M. Bancroft & Son, treasurer's bond	15.00
February 7	Miss J. M. Ham, salary for January	45.00
15	D. Gillies' Sons, printing	66.02
March 8	Arthur D. Marble, auditor	3.00
	Harvard Quartet, music, February 13, 1907	25.00
	Hub Engraving Company, plates	2.81
	Miss J. M. Ham, salary to March 1	55.00
	D. Gillies' Sons, circulars	4.50
14	B. D. B. Bourne, stereopticon	10.00
	Boston Society of Civil Engineers, rent to February 28	100.00
21	Daggett's Orchestra, music, March 13	15.00
	Thomas P. Taylor, stereopticon	10.00
	Miss J. M. Ham, salary to April 1	50.00
	Charles W. Sherman, salary to March 31	75.00
	Charles W. Sherman, postage and express	8.00
April 15	Samuel Usher, printing	8.00
	Hub Engraving Company, plates	16.78
	W. H. Hughes, binding JOURNAL and index	5.50
	Bacon & Burpee, reporting January, February, and March meetings	70.00
	Robert J. Thomas, advertising agent, to April 1	82.75
17	Samuel Usher, March JOURNAL and reprints	360.50
	Willard Kent, salary as Secretary to March 31	50.00
	Willard Kent, sundry expenses	52.30
May 2	Samuel Usher, printing advance proofs	7.50
	Miss J. M. Ham, salary to May 1	50.00
8	Miss J. M. Ham, sundry expenses	39.72
	W. N. Hughes, envelopes	48.60
June 5	Miss J. M. Ham, salary to June 1	50.00
	Samuel Usher, lists of members	150.50
	W. N. Hughes, envelopes	24.00
19	Hub Engraving Company, plates	9.90
	John C. Chase, floral wreath for funeral of V. C. Hastings	10.00
	Miss J. M. Ham, salary for June	50.00
	Charles W. Sherman, salary to July 1	75.00
	Charles W. Sherman, postage and express	6.50
July 26	Miss J. M. Ham, salary for July	50.00
	Miss J. M. Ham, sundry expenses	39.79
	Amount carried forward	$1,759.28

	Amount brought forward	$1,759.28
July 26	Boston Society of Civil Engineers, rent to May 31,	100.00
	Willard Kent, salary to July 1	50.00
	Willard Kent, telephones	18.70
August 9	Samuel Usher, circulars	2.00
	R. J. Thomas, advertising agent	77.25
20	Samuel Usher, June JOURNAL	264.65
September 5	W. N. Hughes, envelopes and printing	62.00
	Miss J. M. Ham, salary for August	50.00
26	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage and expenses	7.00
	Whitehead & Hoag Company, badges	45.50
	Thomas P. Taylor, stereopticon	30.40
	The American Society of Mechanical Engineers, electrotypes	48.50
	Mary A. Powell, reporting twenty-sixth annual convention	66.00
October 23	Miss J. M. Ham, salary for September	50.00
	Miss J. M. Ham, sundry expenses	70.45
	Boston Society of Civil Engineers, rent to August 31,	100.00
	Willard Kent, salary to October 1	50.00
	Willard Kent, sundry expenses	19.80
November 7	Miss J. M. Ham, salary for October	50.00
	Springfield Photo-Engraving Company, plates	19.32
	Hub Engraving Company, plates	6.77
19	W. N. Hughes, printing	13.50
	Samuel Usher, advance copies	28.00
	Hub Engraving Company, plates	12.36
December 13	Miss J. M. Ham, salary for November	50.00
	R. J. Thomas, advertising agent	74.00
	William E. Whittaker, drafting	2.50
	Hub Engraving Company, plates	19.90
	Thomas P. Taylor, stereopticon	10.00
20	Boston Society of Civil Engineers, rent to November 30	100.00
1908.		
January 3	R. J. Thomas, advertising agent	72.00
	Miss J. M. Ham, salary for December	50.00
	Miss J. M. Ham, sundry expenses	20.81
	Samuel Usher, September JOURNAL and reprints	427.64
	Hub Engraving Company, plates	4.23
	Charles W. Sherman, salary to December 31	75.00
	Charles W. Sherman, postage, etc.	8.00
	Willard Kent, salary to December 31	50.00
	Amount carried forward,	$4,040.56

	Amount brought forward	$4,040.56
January 3	Willard Kent, sundry expenses	47.25
	Lewis M. Bancroft, treasurer's salary to December 31	50.00
	Bacon & Burpee, reporting November and December meetings	59.25
	Thomas P. Taylor, stereopticon	10.00
	The Brunswick, music, December meeting	15.00
		$4 222.06

Report of the Editor.

Boston, January 8, 1908.

To the New England Water Works Association: — I present the following report for the Journal of the New England Water Works Association for the year 1907.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year, including the cost of the December Journal and reprints, bills for which were received too late to pay in 1907, and which are, consequently, not included in the Secretary's and Treasurer's statements; and a comparison with the conditions of the seven preceding years.

Size of Volume. — The volume is somewhat larger than for the preceding year, and larger than any preceding annual volume, with one exception.

Illustrations. — The total cost of illustrations for the year has been $228.68, or 8.7 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Some few reprints have also been furnished to members who have contributed discussions, themselves almost in the nature of papers. The net cost to the Association for reprints and advance copies has been $133 (assuming that the December reprints chargeable to members are promptly paid for), amounting to $7.40 for each of the eighteen papers published during the year.

Circulation. — The present circulation of the Journal is:

Members, all grades	702
Subscribers	59
Exchanges	24
Total	785

an increase of 18 over the preceding year.

Advertisements. — The December issue contained 28½ pages of paid advertising, which, if maintained throughout the year, would mean an annual income

from this source of $1 940. A year ago the figures were 26.08 pages and $1 740, showing considerable increase during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $30.70 have been sold. There has been no corresponding expense, so this represents a net gain. The net gain up to a year ago had been $109.05, so that the total net gain from this source to date is $139.75. There is still a fair stock of specifications on hand, probably about $25.00 worth if sold at retail.

The last two issues of the year have been very much delayed in their publication, and the December issue has gone to subscribers only this week, consequently bills for printing it and for reprints could not be paid in time to be included in the 1907 bills as listed by the Secretary and Treasurer. They have, however, been included in this report, and they amount to $565.20. I know of no other outstanding bills against the Association on account of the Journal.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXI, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1907.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	73	35	108	–	31	4	2	145	5
2	June	73	9	82	–	32	4	2	120	16
3	September	117	17	134	–	31	4	3	172	16
4	December	166	10	176	8	31	4	13	232	60
	Total	429	71	500	8	125	16	20	669	97

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXI, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1907.

Receipts.		Expenditures.	
From advertisements	$1 728.75	For printing JOURNAL	$1 508.99*
From sale of JOURNALS	256.17	For preparing illustrations	150.68
From sale of reprints	7.60	For editor's salary	300.00
Subscriptions	167.75	For editor's incidentals,	38.00
	$2,160.27	For advertising agent's commissions	306.00
		For reporting	195.25†
Net cost of JOURNAL	483.15	For reprints and advance copies	144.50
	$2 643.42	Gross cost of JOURNAL	$2 643.42

* Including $522.20 for December JOURNAL (not yet paid).

† Including $43.00 for December reprints (not yet paid).

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV TO XXI, INCLUSIVE, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	VOL. XIV. 1899-1900.	4 Numbers of VOL. XV. 1900-1901.	VOL. XVI. 1902.	VOL. XVII. 1903.	VOL. XVIII. 1904.	VOL. XIX. 1905.	VOL. XX. 1906.	VOL. XXI. 1907.
Average edition (copies printed),	1 100	1 200	1 200	1 200	900	900	900	1 085
Average membership	583	586	571	587	596	625	665	693
Circulation at end of year	640*	617*	648*	656*	667	705	767	785
Pages of text	345	363	403	430	491	587	495	500
Pages of text per 1 000 members,	600	618	707	733	824	939	745	722
Total pages, all kinds	485	536	584	619	794*	784	662	669
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254	995	964
GROSS COST:								
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88	3.95
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87	3.82
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67	5.85	5.70
Per member per 1 000 pp. text	9.71	10.13	10.60	10.72	10.00	8.91	7.81	7.62
NET COST:								
Total	$347.55	$332.90	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15
Per page	.72	.62	1.07	1.25	.82	1.37	.58	.72
Per member	.60	.57	1.09	1.31	1.09	1.72	.58	.70
Per member per 1 000 pages	1.23	1.06	1.87	2.12	1.30	2.20	.88	1.04
Per member per 1 000 pp. text,	1.73	1.57	2.71	3.05	2.22	2.93	1.18	1.39

* Exclusive of three hundred sample copies.

On motion duly seconded the Editor's report was accepted as read and placed on file.

THE PRESIDENT. The next thing on the program is the report of the Finance Committee. My impression is that the chairman of that committee is ill, and I think Mr. Cassell is the ranking member.

MR. CASSELL. Mr. President, owing to the absence of the two senior members of the Finance Committee — I mean in point of service only — I find that I, the infant member of the committee, have been called upon to read the report of the Finance Committee.

REPORT OF FINANCE COMMITTEE.

BOSTON, MASS., January 6, 1908.

In compliance with Section 5 of Article 6 of the Constitution of the New England Water Works Association, the Finance Committee, with the exception of Mr. Arthur D. Marble, who could not attend on account of illness, met this day at the headquarters of the Association and attended to their duties in auditing the accounts of the Treasurer and Secretary.

We examined the Secretary's books, verified the accounts, and found the total receipts, $5 179.10, as stated, to be correct, which amount he has turned over to the Treasurer, as his vouchers testify.

We examined the Treasurer's accounts and found that his receipts from the Secretary agree with the amount as stated above. We also examined the record of his payments and find them correctly recorded and properly certified and vouched for.

The disbursements amount to $4 222.06.

We find the invested fund in two savings banks, with interest to date, namely, $62.98 and $49.75, amounts to $2 802.95, and cash on hand to be $1 677.35, all as stated in the Treasurer's report, making a total of $4 480.30 as a balance on hand for the beginning of the year.

Your committee desires to commend the work of the Treasurer, Secretary, and Assistant Secretary for the clear and concise manner in which the books and finances of the Association are kept, and to acknowledge the courtesies extended by them.

Respectfully submitted,

WILLIAM E. MAYBURY.
GEORGE CASSELL.

On motion duly seconded the report of the Finance Committee was accepted and placed on file.

THE PRESIDENT. It seems proper at this time to take up the matter of the acceptance or rejection of the Treasurer's report, it having been passed on and certified as being correct.

On motion duly seconded the report of the Treasurer was accepted and placed on file.

PIPE SPECIFICATIONS.

THE PRESIDENT. The chairman of the Committee on Standard Specifications for Cast-Iron Pipe is present and desires to make a few remarks.

MR. DEXTER BRACKETT. The committee has no formal report to make, but as I have had during the past year some correspondence with the chairman of a committee of the American Water Works Association having this question under consideration, I think it may interest the members of this Association to know what is being done in the matter of standard water-pipe specifications by the American Water Works Association, as it may affect the action of this Association.

At the annual convention of the American Water Works Association held at Toronto in June, 1907, a committee of that association reported a form of standard specifications for cast-iron water pipe which follows very closely the wording and the tables giving standard dimensions and weights that have been adopted by this Association. They have, however, suggested some changes, the principal one being a reduction in the number of standard classes; and they have added a further set of tables giving standard thicknesses and weights for heavier pipes. The standards of the New England Water Works Association have 10 classes adapted for heads from 50 feet to 500 feet inclusive, while they have presented 8 standards adapted for heads from 100 feet to 800 feet.

They have not as yet got their specification in a form which your committee is willing to recommend for your approval. The differences are slight, but some of the changes proposed are not, in our opinion, any advance over the specifications which we have adopted.

It will certainly be much better if a standard which will be used by the entire country can be agreed upon, and we hope that this

may be accomplished and that the matter may be brought to your attention later, but your committee does not believe in the adoption of another specification which would be but little, if any, better than the one which has been already used for several years. The fact that your Secretary has sold during the past year about three hundred copies of the standard specifications, in addition to what have been quite generally distributed throughout the country in past years, shows that it is being used.

THE PRESIDENT. The next item on the program is the report of the tellers appointed to canvass ballots. We would like to hear from Mr. Arthur F. Ballou.

ELECTION OF OFFICERS.

MR. BALLOU. Your tellers have carefully counted the ballots and examined them, and present the following results:

REPORT OF TELLERS OF ELECTION.

Whole number votes cast	213
Not properly endorsed	9
For President.	
ALFRED E. MARTIN	199
For Vice-Presidents.	
M. N. BAKER	200
GEORGE A. KING	200
MICHAEL F. COLLINS	200
GEORGE F. WEST	200
WILLIAM F. SULLIVAN	199
ROBERT A. CAIRNS	201
For Secretary.	
WILLARD KENT	202
For Treasurer.	
LEWIS M. BANCROFT	200
For Editor.	
CHARLES W. SHERMAN	200
For Advertising Agent.	
ROBERT J. THOMAS	201
For Additional Members of Executive Committee.	
GEORGE W. BATCHELDER	200
D. N. TOWER	200
GEORGE A. STACY	201
For Finance Committee.	
GEORGE CASSELL	200
JOHN C. CHASE	200
WILLIAM E. MAYBURY	201

ARTHUR F. BALLOU.
S. A. AGNEW.

THE PRESIDENT. The result of this election seems to be practically unanimous. I think we would all like to hear something from our newly elected president, Mr. Martin, who has been a member of our Association for twenty-two years, and is known and respected by the whole Association. [Applause.]

MR. ALFRED E. MARTIN. *Gentlemen of the New England Water Works Association,* — I have no doubt Mr. Whitney is just as pleased to hear from me at this time as we were to hear from him a year ago.

I thank you sincerely from the bottom of my heart for giving me the privilege and honor of presiding over our Association, a privilege and honor which in the wildest flights of my imagination I never hoped would be mine. [Laughter.] It is true I have been a member twenty-two years; I was elected at the memorable meeting — I think it was memorable, at least judging by reports; I wasn't present at the time — when the two associations, the American and ours, met together in Boston in 1885.

I assure you, gentlemen, that I appreciate this honor, and that my appreciation is just as great as though I could express it in language that would be more pleasing to you and more satisfactory to me. But I am no orator, and consequently you will have to accept the simple statement of the fact itself. If there are any of you present who have ever seen me in similar positions, you may know that I am a better worker than I am talker. I therefore will not take up more of your time, which is too valuable to be wasted. I thank you, gentlemen, once more. [Applause.]

THE PRESIDENT. We all know that Mr. Martin is a worker, and it seems to us that he is also a very fair talker.

The Secretary has a few applications for membership, which we will put in at this time.

The Secretary read the names of the following four applicants who, having been recommended by the Executive Committee, were elected to membership:

William Atkins McKenzie, Meriden, Conn, engineer connected with the Carnegie Lake, Princeton, N. J.; Milton W. Davenport, New Britain, Conn., chemist in charge of sewage filtration plant; Walter E. Spear, Babylon, N. Y., division engineer, Board of Water

Supply; George W. Cutting, Jr., Weston, Mass., in independent engineering practice.

Mr. Harry L. Thomas, assistant superintendent of water company, Hingham, Mass., read a paper entitled "Experience with a Producer Gas Plant." It was discussed by Messrs. E. H. Gowing, Crowthers, S. H. McKenzie, F. L. Fuller, A. O. Doane, I. T. Farnham, George Cassell, and F. A. Barbour.

Mr. F. F. Forbes, superintendent of water works, Brookline, Mass., read a paper entitled "One Year's Practical Everyday Experience with an Automobile for Business, by a Water-Works Man." It was discussed by Messrs. Dexter Brackett, W. F. Sullivan, Coulters, and J. H. Flynn.

Mr. Freeland Howe, Jr., read a paper entitled "Action of Water on Water Pipes." It was discussed by Messrs. B. B. Hodgman, E. D. Eldredge, A. O. Doane, G. E. Winslow, S. H. McKenzie, E. B. Phelps, and F. L. Fuller.

The meeting then adjourned.

February Meeting.

Hotel Brunswick, Boston, Mass.,
February 12, 1908.

A regular meeting of the Association was held at the Hotel Brunswick, Boston, Mass., on Wednesday, February 12, 1908, at 2 P.M. President Alfred E. Martin occupied the chair, and the following were present:

Members.

S. A. Agnew, J. M. Anderson, M. N. Baker, C. H. Baldwin, L. M. Bancroft, G. W. Batchelder, J. F. Bigelow, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, George Cassell, J. C. Chase, C. E. Childs, H. W. Clark, J. H. Child, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. W. Crawford, F. W. Dean, A. O. Doane, John Doyle, E. D. Eldredge, J. N. Ferguson, W. E. Foss, S. DeM. Gage, F. J. Gifford, A. S. Glover, F. E. Hall, L. M. Hastings, T. G. Hazard, Jr., H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, L. P. Kinnicutt, Morris Knowles, N. A. McMillen, D. E. Makepeace, A. D. Marble, A. E. Martin, W. E. Maybury, F. E. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, R. R. Newman, O. E. Parks, E. M. Peck, J. H. Perkins, W. H. Richards, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, W. F. Sullivan, C. N. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. A. Tilden, D. N. Tower, W. H. Vaughn, R. S. Weston, J. C. Whitney, G. E. Wilde, C.-E. A. Winslow, and G. E. Winslow. — 74.

Associates.

The Anderson Coupling Company, by F. A. Leavitt; Harold L. Bond Company, by Harold L. Bond; Builders' Iron Foundry, by F. N. Connet; Eagle Oil and Supply Company, by John L. Hamilton; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Perrin, Seamans & Co., by Chas. E. Godfrey; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by Fred N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by E. M. Barnard, F. E. Hall, and Charles F. Merrill. — 22.

GUESTS.

F. L. Weaver, Harry Girard, A. H. Weaver, Lowell, Mass.; Frank H. Gunther, Dracut, Mass.; Henry W. Littlefield, of Allen & Reed, Inc., Providence, R. I.; George F. Merrill, Supt., Greenfield, Mass.; Hon. S. O. Bigney, Attleboro, Mass.; A. Fleming, Wm. J. Carroll, Joseph H. White, J. Rodney Ball, Dr. J. T. Collins, Lawrence, Mass.; Charles H. Andrews, Marlboro, Mass.; Hon. G. Louis Richards, Mayor, Malden, Mass.; H. S. Richards, New London, Conn.; L. H. Cornfel, Boston; C. H. Cooley, Westfield, Mass.; Fred M. Hutchinson, Somerville, Mass.; George A. Carpenter, Pawtucket, R. I.; E. E. Pinkham and D. A. Sutherland, Lynn, Mass. — 21.

[Names counted twice — 5.]

The President called upon Mayor Richards, of Malden, who addressed the Association briefly.*

THE PRESIDENT. I now have the pleasure of presenting to you, gentlemen, the Hon. S. O. Bigney, of Attleboro, who, as our friend the Mayor has said, will now proceed to furnish the oratory. Colonel Bigney represents one of the largest manufacturing jewelry establishments in the country, and has had the privilege and honor of serving as a member of the Governor's Council.

COLONEL BIGNEY. *Mr. President and Gentlemen,* — I am glad to note to-day that you are all on the water wagon. The Mayor has told you just what I am going to say, how I am going to say it, etc.; and he has also told you how good looking you are. Well, I agree with him; as I look into your faces I can see that you are all very good-looking, and that is no bouquet at all. I understand, by the way, that you men seldom give up your business after you once get hold of it, but you stay and stay for all time, or as long as you live.

I know you have a lot of business to attend to this afternoon. But as I listened to the tunes which were played by the orchestra over there, a little while ago, I was reminded that this was the birthday of Abraham Lincoln, the greatest American citizen living or dead, without any question. All any one has to do is to read the life of Abraham Lincoln and he will agree with that statement. No man yet has ever done justice to the memory of that great American, nor can he.

It is hard for us to-day to appreciate this splendid heritage which has been passed down to us. We cannot begin to appre-

* A report of Mr Richards' remarks was sent to him for revision, and has not been returned to the Editor up to the time of going to press.

ciate it unless we go back and read afresh the history of that great man's life, and the history of the Civil War, and think of the suffering of those who made it possible for us to enjoy the splendid inheritance which is ours.

Gentlemen, I am pleased to be here to-day; I am glad to look into your faces. Two of my fellow-townsmen from Attleboro are here. We have been doing great work in our town in bettering and increasing the efficiency of our water works. Of course we have been criticised for spending too much money, but we had to do it in order to meet the demands of our community. I feel satisfied that my friends can take care of themselves anywhere, even at home when our next election comes on. I thank you very much, gentlemen, for your kind attention. [Applause.]

The President called upon Mr. Morris Knowles, chief engineer of the Bureau of Filtration, Pittsburg, Pa., to open the consideration of the subject especially assigned for the afternoon, which was, "Filter Operations, Investigations for Additional Supply, and Construction of New Filter at Lawrence, Mass." He was followed by Mr. Arthur D. Marble, city engineer, Lawrence, Mass., who gave a history of the agitation of the subject in Lawrence, finally culminating in the construction of the new filter; Stephen DeM. Gage, biologist, Massachusetts State Board of Health at the Lawrence Experiment Station, who illustrated by lantern slides the construction of the new filter and made some particular reference to the bacterial results obtained by filtration and the effect on the health of the community; Sanford E. Thompson, consulting engineer, who spoke particularly of the collapse of a portion of the roof of the new filter during process of construction; and M. F. Collins, superintendent of water works, Lawrence, who spoke of the matter of typhoid fever.

The general discussion which followed was participated in by Mr. M. N. Baker, Mr. Robert S. Weston, and Mr. Charles N. Taylor.

The Secretary read applications for membership from the following-named persons, all of which had been properly recommended and approved:

Active. — Charles W. Gilbert, Woburn, Mass., student of state and local management of public water supplies; Frank H. Gun-

ther, Dracut, Mass., superintendent, Dracut Water Works; Richard D. Chase, New Bedford, Mass., with National Board of Fire Underwriters; Robert Ridgway, Poughkeepsie, N. Y., Board of Water Supply, New York City.

Associate. — Allen & Reed, Inc., steam, gas, and water-works supplies, Providence, R. I.

The Secretary was instructed to cast the vote of the Association in favor of the applicants above named, and, he having done so, they were declared duly elected members of the Association.

The Secretary read a letter from Mr. S. E. Tinkham, Secretary of the Boston Society of Civil Engineers, inviting the members to attend a meeting of the Society on Wednesday, February 19, at which Mr. Allen Hazen would describe his trip to Australia " and show a large number of lantern slides of the Brisbane Water Works, the Sidney Water Works, the Melbourne Sewerage and Sewage disposal, and many views of public interest."

Mr. George Bowers called attention to the fact that there is now pending before the Massachusetts Legislature a bill appropriating $10 000 for the making of a geological map of the state. The United States government, if the bill is passed, will also make an appropriation for the work equal to the amount appropriated by the state. He spoke of the great importance that such a map would be to water-works interests, and asked the members to urge their representatives in the legislature to vote for the bill, which is Senate Bill No. 47.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 8, 1908.

Present: President John C. Whitney and members D. N. Tower, Robert J. Thomas, A. E. Martin, L. M. Bancroft, George W. Batchelder, George A. King, Charles W. Sherman, and Willard Kent.

Four applications were received and recommended for membership, viz.:

George W. Cutting, Jr., civil engineer, Waltham, Mass.; Milton W. Davenport, chemist in charge of sewerage filtration plant, New Britain, Conn.; William Atkins McKenzie, civil engineer, Meriden, Conn.; Walter E. Spear, Division Engineer, Board of Water Supply, Babylon, Long Island, N. Y.

The committee on investment of funds reported recommending the purchase of bonds of the Lake Shore & Michigan Southern Railway, and, on motion of Mr. Sherman, seconded by Mr. Martin, and amended by Mr. King, it was voted:

The Treasurer be, and hereby is, authorized to invest funds of the Association to an amount not exceeding two thousand dollars ($2 000) in bonds of the Lake Shore & Michigan Southern Railway.

On motion it was —

Voted: That certain persons suspended from membership in the Association for non-payment of dues, which have now been paid, be and hereby are reinstated.

No further business appearing, meeting dissolved.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 12, 1908.

Present: President A. E. Martin and members M. F. Collins, Robert J. Thomas, William F. Sullivan, L. M. Bancroft, D. N. Tower, George A. King, Charles W. Sherman, M. N. Baker, George W. Batchelder, and Willard Kent.

Applications were received and recommended for membership from:

Charles Walter Gilbert, of Woburn, Mass.; Robert Ridgway, of Poughkeepsie, N. Y.; Frank M. Gunther, of Dracut, Mass.; Robert Davenport Chase, of Westfield; and from Allen & Reed, Inc., of Providence, R. I., for associate membership.

Voted: That the June meeting of the Association be held at Plymouth, Mass., and that the President, Secretary, Editor, George A. King, and D. N. Tower, be a committee with full power to make all necessary arrangements.

The subject of the place for holding the next Annual Convention was brought up and, after discussion, the members were unanimously of the opinion that, if suitable arrangements could be made, it should be held at St. John, N. B., and the President, Secretary, Editor, George W. Batchelder, and William F. Sullivan were made a committee to make necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Charles Hermany, chief engineer and superintendent of the Louisville, Ky., Water Company, died at his home in Louisville, on January 18, 1908.

Mr. Hermany was born in Lehigh County, Pa., on October 9, 1830. In 1853 he entered the office of the city engineer of Cleveland, Ohio, and in 1857 he went to Louisville and became connected with the water company. In 1861 he became its chief engineer and superintendent and held the position continuously until his death.

It was under the direction of Mr. Hermany that the filtration experiments were made by Mr. George W. Fuller which mark the beginning of mechanical filtration as a scientific process.

Mr. Hermany was president of the American Society of Civil Engineers in 1904. He was elected an honorary member of the New England Water Works Association on September 14, 1904.

BOOK REVIEW.

Modern Baths and Bath Houses. By Wm. Paul Gerhard, C.E. New York: John Wiley & Sons. 1908. 311 pp., 5¾ x 9¼ inches. Many illustrations. $3.00 net.

To the ordinary reader it would seem that this book must contain almost all that could be written on the subject of baths and bathing. Yet the bibliography composing one chapter of the book covers seven pages and indicates that the subject is by no means exhausted. The book describes not only water baths, but also air baths, mud baths, medicinal baths, etc. The illustrations show all kinds of apparatus, as well as plans and views of baths for various purposes, and sixteen pages are devoted to complete specifications for a municipal bath-house. There is a good index.

NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE MANAGEMENT OF THE TYPHOID FEVER EPIDEMIC AT WATERTOWN, N. Y., IN 1904.

BY GEORGE A. SOPER, PH.D., CONSULTING ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Read March 11, 1908.*]

Mr. President, Members of the Association, and Guests: Before taking up the subject of my paper, I hope the Association will allow me to express my thanks for its kind invitation to come here and tell about the Watertown epidemic. This epidemic may at first seem to be an old story. There is nothing new in the general idea of a typhoid epidemic caused by a public water supply derived from a badly polluted river, and if I had nothing more novel than merely that to relate I should not have come. But there were some features connected with the epidemic, and particularly with its sanitary management, which I believe will be new to you. On these questions particularly I shall welcome a free expression of your opinion.

There is no body before which an account of this kind could be presented to greater advantage, a statement which is warranted by the fact that the New England Water Works Association is composed of practical and scientific men, many of whom have had valuable experience with typhoid and keep themselves abreast of the best measures of avoiding it. It is generally recognized that New England is a source and center of inspiration in sanitary matters, and so far as the prevention of typhoid is concerned, this Association has done its full share to build up and maintain that good reputation.

The typhoid epidemic which is here described occurred in the first few months of 1904 at Watertown, N. Y. It was an uncommonly serious outbreak, numbering about one half as many cases as occurred in the epidemic at Ithaca the year before, and placed Watertown third among the cities of the United States which had typhoid death-rates in excess of 200 per 100 000 of population in the year 1904.

The typhoid history of Watertown for some years prior to this epidemic furnishes an example of the results which generally follow when a polluted river is used as a source of drinking water. The conditions of pollution were evident, but their significance was, apparently, not thoroughly appreciated until too late.

Perhaps the greatest interest which attaches to the epidemic lies in the energetic measures which were taken to stamp it out. If the city had seemed indifferent to the danger of typhoid, it certainly was anxious to make all possible amends when the inevitable catastrophe occurred.

As to the circumstances which led the city to continue for years to use the polluted river as a source of water supply, little has been said or written, so far as I am aware, and it is not my purpose to discuss this matter here. It is possible that indifference to the quality of the water was more apparent than real. The water works were in the hands of a municipal water board composed of citizens of the highest character and intelligence. They had sought and obtained expert sanitary advice on more than one occasion. There is reason to believe that the board was neither unmindful of the danger nor unwilling to take steps to remove it, but it appears that a decision as to the exact nature of the radical measures of protection needed could not, for some reason, be decided on.

The population of Watertown, according to an estimate made by the Census Bureau of the United States Department of Commerce and Labor, was 24 194 on January 1, 1904. The area of the city is somewhat over 3 000 acres; its assessed valuation of property exceeded $10 000 000. It is a manufacturing city, owing its prosperity largely to water-power developments on the Black River at this point. The location of Watertown with respect to the Black River is shown in Fig. 1.

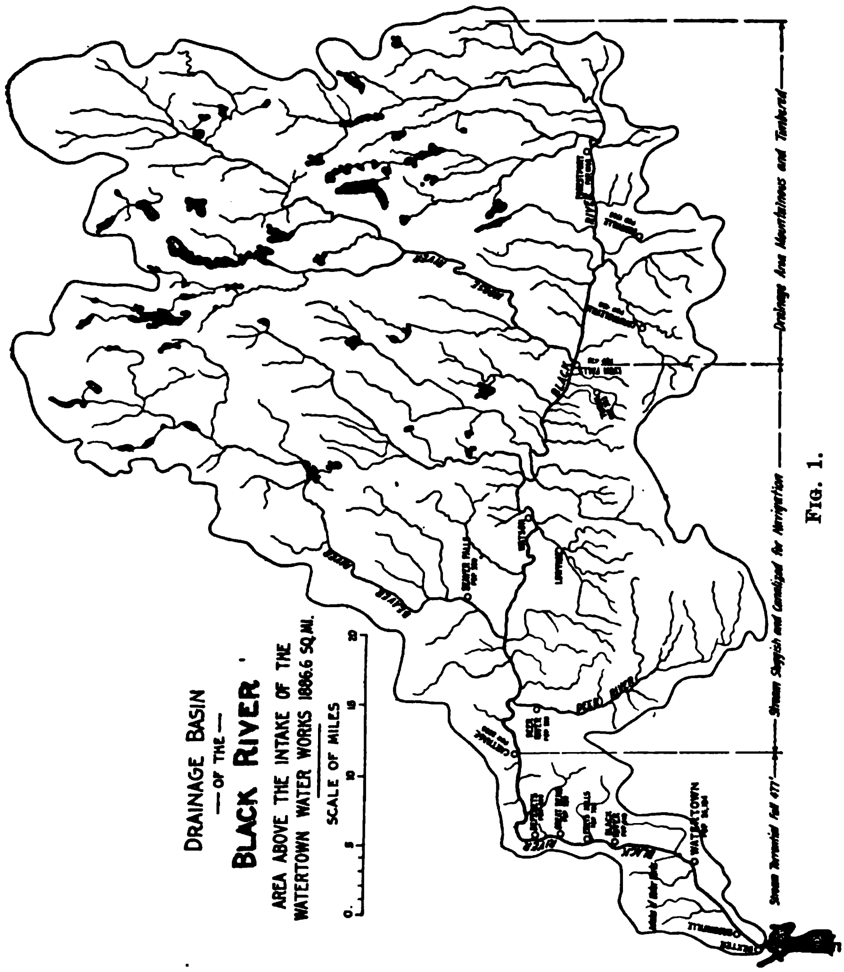

DRAINAGE BASIN
— OF THE —
BLACK RIVER
AREA ABOVE THE INTAKE OF THE WATERTOWN WATER WORKS 1886.6 SQ.MI.
SCALE OF MILES
0
5
10
15
20
WATERTOWN
BLACK RIVER
MOOSE RIVER
BEAVER RIVER
DEER RIVER
Stream Torrential Fall 477'
Stream Sluggish and Canalized for Navigation
Drainage Area Mountainous and Timbered

FIG. 1.

I.

PREVIOUS HISTORY OF TYPHOID AT WATERTOWN.

For many years typhoid fever had been unduly prevalent at Watertown, as is shown in Table I, in which the statistics for the city and state are given for twenty years.

TABLE I.

STATISTICS OF TYPHOID FEVER AT WATERTOWN, N. Y., FOR THE TWENTY YEARS 1885–1904.

Year.	Population.	Deaths from All Causes.	Deaths from Typhoid.	Per Cent. of Deaths from Typhoid to Deaths from All Causes.	Deaths from Typhoid per 100 000 Living.
1885	12 700	196	5	2.55	39
1886	13 100	229	5	2.18	38
1887	13 500	216	6	2.77	44
1888	13 900	296	8	2.70	58
1889	14 300	217	5	2.31	35
1890	14 700	234	7	2.99	47
1891	15 400	271	7	2.58	45
1892	16 100	376	12	3.19	74
1893	16 800	333	10	3.00	59
1894	17 500	323	15	4.61	85
1895	18 200	312	31	9.90	169
1896	18 900	331	11	3.32	58
1897	19 600	312	16	5.12	82
1898	20 300	340	22	6.47	108
1899	21 000	351	19	5.41	90
1900	21 000	397	24	6.04	110
1901	22 400	347	13	3.74	57
1902	23 200	317	16	5.04	69
1903	23 900	356	19	5.33	79
Average for Watertown for nineteen years,				4.17	71
Average for N. Y. state for same period,				1.3	25
For the epidemic year, 1904, at Watertown			47	12.81	194

NOTE. Since the epidemic the typhoid death-rate has been, per 100 000 of population, as follows: 1905, 24; 1906, 50; 1907, 37.

After 1894 there had been more typhoid than formerly. For the nine years preceding the epidemic of 1904 the average typhoid

death-rate had been 83 per 100 000 of population. The average for the whole state of New York for the twenty years prior to 1904 was 25, or less than one third that for Watertown. There had been, in the nine years previous to the epidemic, an average of 56 deaths from typhoid to 1 000 deaths from all causes in Watertown, while for the whole state, for the twenty-year period mentioned, the ratio had been 16 to 1 000. The records of the Board of Health show that typhoid existed at every season of the year, and that at various times it had been epidemic.

In 1895 two epidemics of typhoid occurred. One of these extended through April and May, and the other from August to December. The total number of deaths from typhoid fever in that year was more than twice that for the year preceding and three times that for the year which followed.

During the epidemic which occurred in the spring of 1895 suspicion centered upon the public water supply and the Board of Water Commissioners caused an investigation to be made to determine whether this was the source of the trouble. This investigation was made by the late Prof. Wyatt Johnston, the distinguished sanitarian, of McGill University, Montreal. The autumn epidemic was investigated by a committee of the Watertown Board of Health.

These two investigations, although made nearly ten years before the epidemic with which we are here chiefly concerned, throw such a strong light upon the conditions which led to the outbreak of 1904 that it seems desirable to pause for a moment to consider them.

The spring epidemic of 1895. The number of cases of typhoid which occurred in the spring epidemic of 1895 was, according to Professor Johnston's report to the Water Commissioners, 63. According to the records of the health office the number was 55. The Board of Health committee which investigated the epidemic which took place later in the year referred to the number in the spring outbreak as 80. The exact number cannot be ascertained, nor is it necessary that it should be. It is sufficient to note that an epidemic undoubtedly occurred in the spring of 1895.

Many circumstances led Dr. Johnston to suspect that the public water supply was the cause of the epidemic. Among fifty persons

suffering from typhoid fever, milk had been received from twenty-one peddlers, of whom only three had more than three cases on his route. The cases were distributed and not confined to any one section of the city. All of the patients had been regular drinkers of the public water supply. No one was ill who made it a regular practice to drink only boiled or filtered water. Most of the cases appeared after an unusual rise in the river; a freshet occurred between April 10 and 13, and most of the cases were recognized between April 20 and May 1.

The net result of Dr. Johnston's investigation was the opinion that the epidemic had come from the water supply. The supply had become infested with typhoid germs, in his judgment, from people in the many mills and other buildings which existed on the Black River above Watertown. He pointed out that unless these sources of pollution were remedied, typhoid fever would continue to be prevalent in Watertown and epidemics would occur from time to time. The danger to public health lay not in the volume of refuse which entered the stream, but in its quality; a large amount of factory drainage was far less liable to lead to disease than a small amount of sewage from water closets or the contents of privies. The existence of many possible points of pollution prevented the Black River from being regarded as a source of safe drinking water at Watertown unless the water was purified.

Dr. Johnston recommended the consideration of a plan for filtering the water, and advised that, pending such purification, a thorough inspection be made of the watershed, followed by the removal of all sources of direct pollution, especially privies, and the rigid suppression of nuisances in the neighborhood of the intake. Finally, he recommended that the intake be moved so as to be less liable to receive water from a polluted brook which entered the river nearby, and farther from the drainage of a neighboring cemetery.

Some of these recommendations were carried out, as we shall see later on. It was impossible, however, to remove the sources of pollution, "especially privies," which, as it will also appear, increased greatly in number as the Black River above Watertown was developed for mill purposes in succeeding years.

The second epidemic of 1895. According to the report of the

committee of the Board of Health which investigated the second epidemic of 1895 there were, in this latter outbreak, 180 persons attacked. Thirty-seven cases were accounted for on the theory that in September the milk supply of one of the numerous milk peddlers in Watertown became contaminated. The other cases were believed to have been caused by a contamination of the public water supply. The worst sources of pollution of the Black River were carefully described and mapped by Messrs. Boyer and Armstrong for this committee.

In concluding their report the committee recommended that the water supply be protected against the pollution which had, on two separate and recent occasions, caused much sickness and death in the city. The cases are reported to have occurred as follows: August, 56; September, 30; October, 63; November, 20; December, 12.

II.

THE PUBLIC WATER SUPPLY FROM THE BLACK RIVER.

The Water Works.

The drinking water supply of Watertown is taken from the Black River at a point about two miles about the city, as shown in Fig. 2. Here there is an arm of the river which has been dammed off from the main stream, making a stretch of quiet water about three quarters of a mile long, from two hundred to six hundred feet wide, and something less than eight feet deep. This is called the settling basin, and from its lower end the water for the city is drawn. The dam failed and was destroyed in December, 1901. It was rebuilt in 1902.

From a pumping station on the river bank the water was, at the time of the epidemic of 1904, pumped to a reservoir situated at an elevation of about 150 feet above the level of the stream. From here it flowed to the consumers by gravity. The reservoir capacity was about 5 000 000 gallons and the average daily consumption about 4 000 000 gallons. Theoretically, water taken in at the pumps should reach the majority of consumers within forty-eight hours.

No irregularity in the operation of the plant occurred after the dam forming the settling basin failed in 1901. A plant of rapid

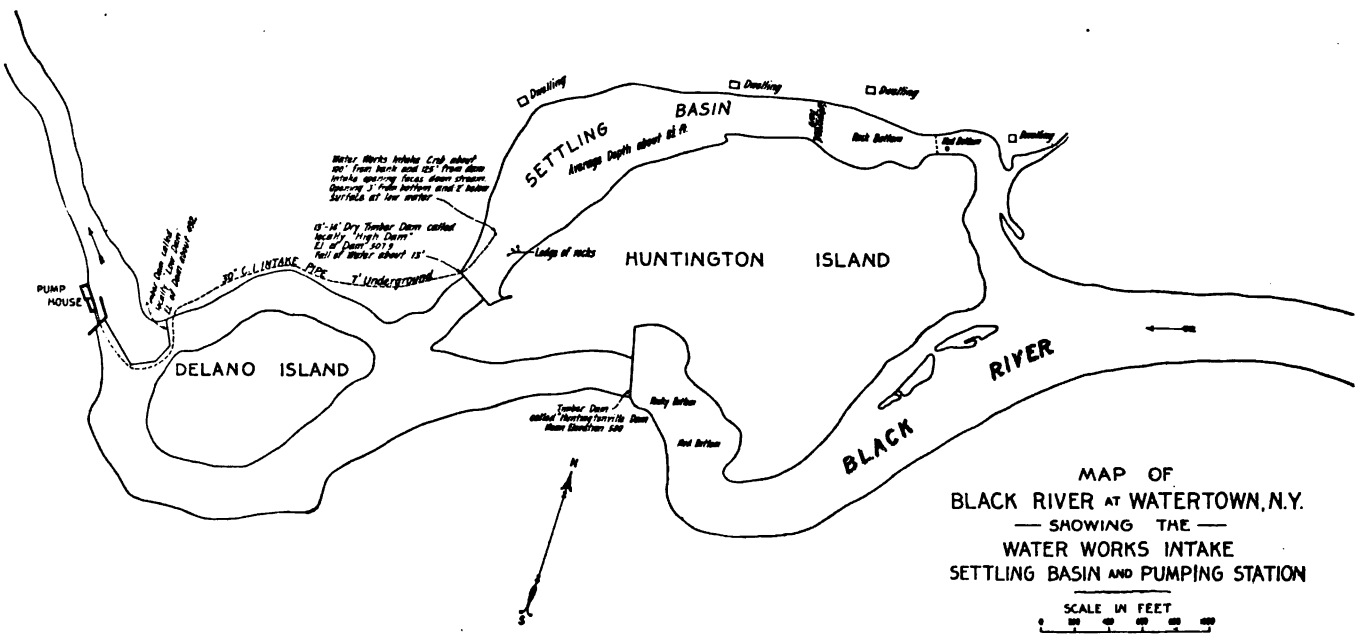

MAP OF
BLACK RIVER AT WATERTOWN, N.Y.
— SHOWING THE —
WATER WORKS INTAKE
SETTLING BASIN AND PUMPING STATION
SCALE IN FEET
SETTLING BASIN
Average Depth about
HUNTINGTON ISLAND
DELANO ISLAND
BLACK RIVER
PUMP HOUSE
Dwelling
Dwelling
Dwelling
Dwelling
Rock Bottom
Ledge of rocks
30" C. I. INTAKE PIPE
7' Underground
Water Works Intake Crib about
100' from bank and 125' from dam.
Intake opening faces down stream.
Opening 3' from bottom and 2' below
Surface at low water
13'-14' Dry Timber Dam called
locally "High Dam"
El. of Dam 507.9
Fall of Water about 15'
Timber Dam
called "Huntingtonville Dam"
Rock Bottom
N
S

FIG. 2.

filters, designed by Allen Hazen, was begun in the autumn of 1903, and has been in service at the pumping station since the fall of 1904.

Quality of the Water.

The water of the Black River is naturally clear but colored with vegetable matter from the forests of the Adirondacks. It is soft and remarkably free from mineral matter except for a small amount due to mill drainage.

The quality of the water is likely to change rapidly with the changes which take place in the volume of the flow of the river. The flow varies from about 600 cubic feet per second to 18 000 cubic feet per second. The turbidity seldom rises above 200 parts per million as measured by the silica scale, and is usually very much lower than this figure. The water is improved somewhat in quality by passing through the sedimentation basin, but such figures as are at hand do not indicate that there is often a reduction exceeding about 50 per cent. in the numbers of bacteria. The chlorine in the river water is well above 0.3 parts per million, which is the normal in this vicinity. Presumptive tests for coli indicate fairly well the polluted condition of the river. Many analyses of the water have been made in connection with the operation of the filter plant, which was put in operation subsequent to the epidemic, but I am indebted to Mr. Francis F. Longley, who was for a time in charge of the operation of these works, for my information concerning this matter. Table II shows the results of some of Mr. Longley's chemical analyses.

TABLE II.
RESULTS OF CHEMICAL ANALYSES OF BLACK RIVER WATER.
(Parts per million.)

Date.	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Chlorine.
October 4, 1904	0.186	0.030	0.001	0.15	0.90
November 2, „	0.112	0.012	0.001	0.05	1.05
November 28, „	0.074	0.002	0.002	0.10	1.20
December 18, „	0.092	0.020	0.002	0.05	.0.90
January 9, 1905	0.116	0.014	0.003	0.10	1.00
February 10, „	0.078	0.006	0.001	0.25	1.25
February 28, „	0.072	0.006	0.001	0.15	1.15
March 20, „	0.216	0.128	0.003	0.20	1.10

So far as I am aware, no analyses of Black River water were made which adequately show the condition of the Watertown supply immediately before or during the epidemic. One sample was taken through the ice near the intake on February 15 and sent for analysis to Dr. R. M. Pearce, of the Bender Hygienic Laboratory at Albany. Dr. Pearce reported that this sample gave 14 200 bacteria per cubic centimeter on gelatine, and 280 on agar. The bacteria liquefied the gelatine with a "moderate putrefactive odor." Gas of the type characteristic of the colon bacillus was found.

The analysis shown in Table III, made by Mr. Longley during rises in the river one year later, perhaps give some idea of the conditions.

TABLE III.

RESULTS OF ANALYSES FOR BACILLUS COLI COMMUNIS IN WATER FROM THE INTAKE OF THE WATERTOWN WATER WORKS.

(By the word "gas" is meant 20 per cent. or more gas in dextrose broth.)

Month.	Average Discharge of River in Cu. Ft. per Second.	Results of Analyses.			
		Number Samples Examined.	Per Cent. Samples of 0.1 c.c. showing Gas.	Per Cent. Samples of 1.0 c.c. showing Gas.	Per Cent. Samples of 10 c.c. showing Gas.
October, 1904	4 700	11	9	91	100
November, ,,	1 920	18	33	100	100
December, ,,	1 650	20	35	95	100
January, 1905	2 640	17	47	100	100
February, ,,	2 380	15	20	93	100
March, ,,	4 010	20	50	90	100
April, ,,	11 350	15	27	80	100
May 1–10, ,,	6 905	6	0	66	100
		122	32	92	100

Physical characteristics of the Black River. The Black River rises in the heart of the Adirondacks, flows in an irregular, southwesterly direction, and empties into Lake Ontario. The distance from the mouth of the stream to the head of its principal tributary is 132 miles. Its total drainage area as given by the Report of the Board of Engineers on Deep Waterways, is 1903.2 square miles. The drainage area with some of the larger villages is shown in

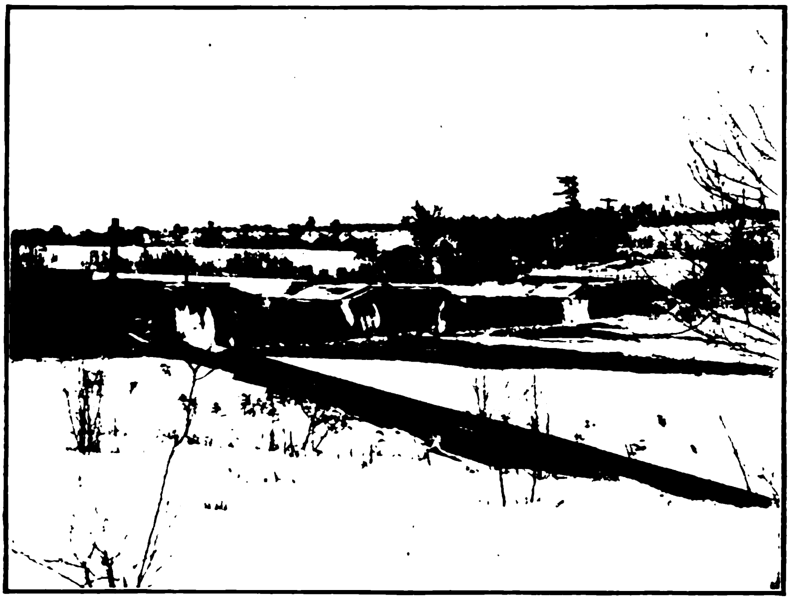


FIG. 1. Intake of the Watertown Water Works, showing the Supply Main in the Foreground.

FIG. 2. Pump House of Watertown Water Works.

Fig. 1. The area above the intake of the water works is given by the same authority as 1 886.6 square miles.

The drainage area may be divided into two parts: a sparsely populated catchment area, which lies almost exclusively in the Adirondack Mountains, and a much more thickly populated, steep, narrow valley from Carthage, past Watertown to Lake Ontario. Parts of the upper portion of this catchment area have a rapid fall which sends down the waters from the rains and melting snows rapidly. In the distance of twenty miles from Carthage to Lake Ontario there is a fall of 477 feet. Through this valley the river flows in a turbulent and sometimes destructive manner. A large amount of the power due to the fall has been developed and is utilized by mills.

In 1902 there were on the drainage area of the Black River and its tributaries, according to the report of the New York State Water Storage Commission of 1903, forty-four dams, furnishing an aggregate of 76 000 horse-power to mills situated on the streams. The value of these mills was estimated at $12 302 100 and the annual value of their product at $15 101 440. There were 5 349 hands employed. Many of these mills were situated at Watertown, but, as will be seen presently, there were several villages along the Black River between Watertown and Carthage where mills, factories, and dwellings crowded the banks. There were a few mills beyond Carthage, at Lyon Falls, and elsewhere.

Sanitary condition of the Black River above Watertown. Through the coöperation of the Watertown Board of Health and the Water Commissioners of the city a careful sanitary inspection was made in 1895 of the shores of the Black River from Watertown to Carthage, a distance of seventeen miles. In this distance there were four villages which, with isolated country houses, had an aggregate population of over five thousand persons. Sketches of a few of these villages as they existed in 1895 are shown in Fig. 3. It appears, upon reliable testimony, that the population in this district had increased about fifty per cent. by 1904. An entirely new village, with a population of between four and five hundred persons, had grown up about a large paper mill at Deferiets, about ten miles above Watertown. To accommodate these people a sewerage system had been built to carry their sewage to the river.

In fact, sewage and other drainage entered from all the villages and mills without any restriction.

In the territory between Watertown and Carthage there were, in 1895, 165 buildings which drained into the stream. There were

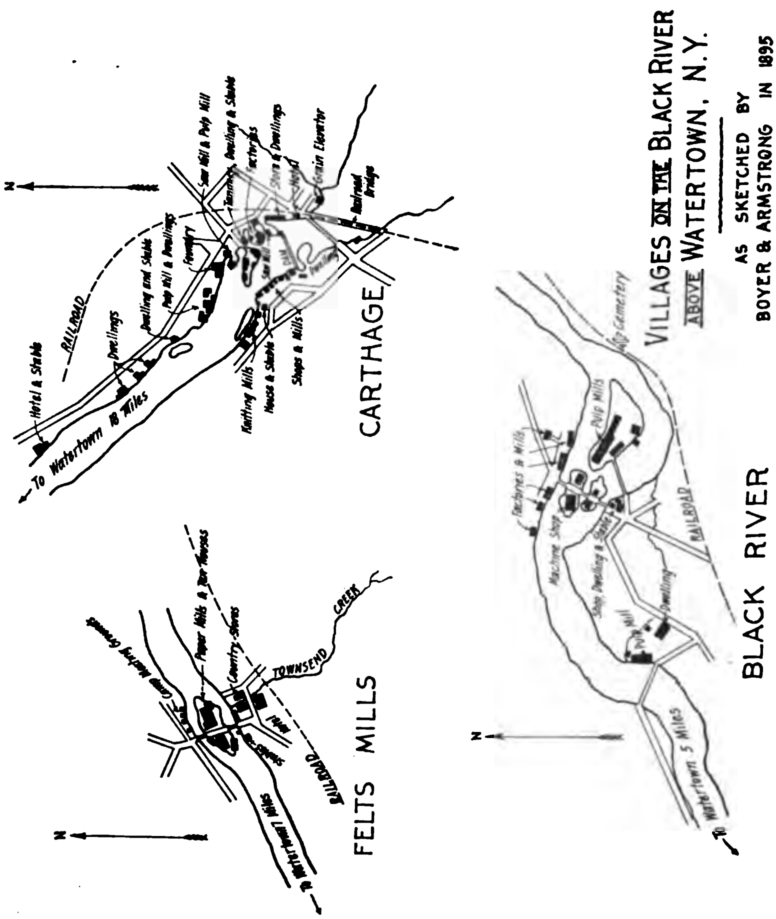


FIG. 3.

82 privies, 17 stables for horses, cattle, and hogs, 10 paper mills, 4 stores, 3 hotels, 2 bakeries. 15 shops of different kinds, and 5 other buildings used for different purposes. The 82 privies were used by about 740 persons and were located directly over the stream, or on its bank, and discharged their contents into the river.

FIG. 1. Town of Black River, looking from the South Side of the Stream. This is five miles above the intake of the Watertown Water Works.

FIG. 2. Felts Mills, Seven Miles above the Intake of the Watertown Water Works.

The manure from the 17 stables was either thrown into the river or piled upon the bank, whence it drained into the stream. In addition to the 740 people whose excreta ordinarily passed directly into the river, about 6 000 to 7 000 people from different parts of the country attended annually a camp meeting held on the banks of the stream at Felt's Mills, seven miles above the intake of the Watertown water works. At this point four privies stood directly on the slope of the bank.

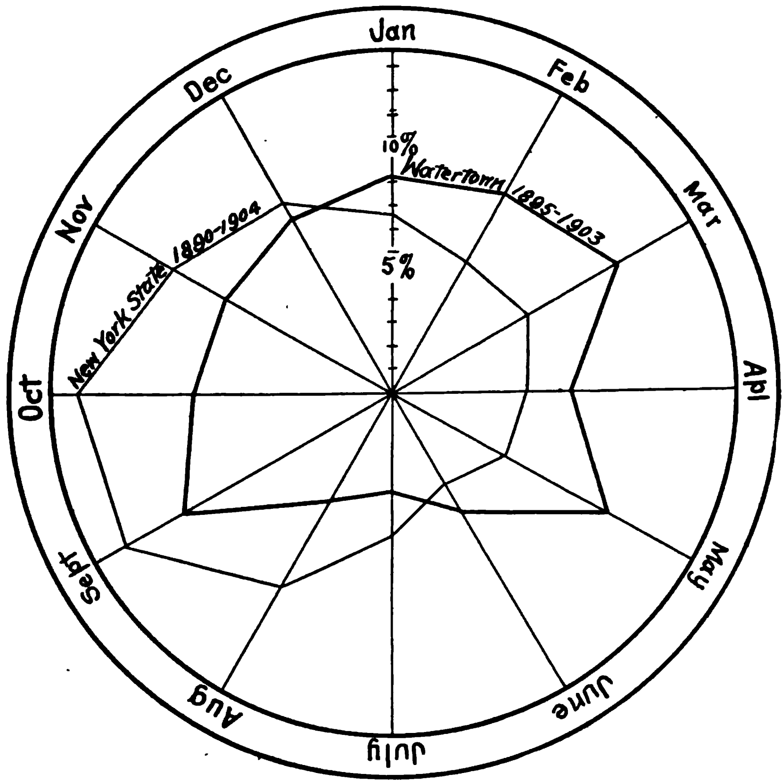


FIG. 4. Distribution of Typhoid Deaths through the Year in Watertown and New York State. The Distribution in the United States corresponds closely with that in New York State. The Peculiarities of the Watertown Curve suggest that the River Water has been a Leading Cause of Typhoid.

It seems unnecessary to point out the danger which these insanitary conditions represented. Aside from the probability that cases of typhoid fever existed every year among the persons who used the privies and sewers, not to mention persons who were chronic bacillus producers, the river was made the disposal place of refuse of every kind. Manure entered it from stables. It is well known that the manure of stables commonly contains human dejecta. It should also be remembered that when typhoid fever occurs in the country, it is usual to throw the stools and urine down the banks of the nearest stream to get rid of it. The Black River was, then, a very dangerous stream from which to take drinking water.

Ineffectiveness of State rules adopted for the protection of the Black River water supply. At the request of the Water Commissioners of Watertown, the State Board of Health, in 1896, formulated rules for the protection of the waters of the Black River from pollution above the intake of the water supply of the city of Watertown. These rules and regulations were made in virtue of Section 70 of Chapter 661 of the state laws of 1893, which empower the State Board of Health " to make rules and regulations for the protection from contamination of any or all public supplies of potable waters and their sources within the state "and "to impose penalties for the violation thereof and the non-compliance therewith."

As is the custom in New York state, the rules were published for six weeks in the principal papers of the district, in this case at Watertown, Carthage, and Lowville, and a certificate to this effect, together with a certified copy of the rules, having been filed in the office of the county clerk of Jefferson County, on April 30, 1896, the rules became law.

The Water Commissioners of Watertown thereafter had the legal right to insist that all dangerous pollution be kept out of the Black River above Watertown. But, as another provision of the public health law compelled the commissioners to bear the expense which this work incurred and also to make good any financial loss to mills and villages which might result, the cost of enforcing the regulations made protection of the water supply in this manner seem impracticable. The law was not enforced.

FIG. 1. Great Bend, from the North Side of the Stream. This is about eight miles above the intake of the Watertown Water Works.

FIG. 2. Deferiets, Ten Miles above the Intake of the Watertown Water Works. A sewer empties into the Black River at this point.

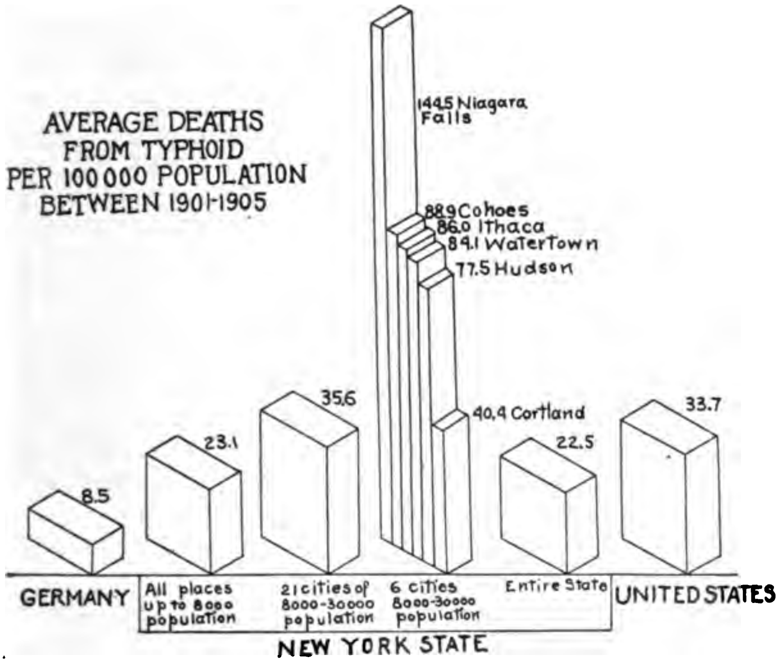


FIG. 5. Comparison between Typhoid Death-Rates for Germany, New York State, and United States. Also rates for six small cities in New York as compared with twenty-one other cities of the same in class New York State. The prevalence of typhoid at Watertown is thus made evident.

III.

THE EPIDEMIC OF 1904.

A study of the weather conditions preceding the epidemic of 1904 discloses some matters of particular interest.

The Weather.

To begin with, in the month of October, 1903, there were excessively heavy rains. These were followed by a long term of cold weather: the November of 1903 was decidedly colder than the average November. After the 18th of November the maximum daily temperature on the drainage area of the Black River was

generally below 32 degrees. The precipitation was light. The weather through most of the month of December was severely cold, the average temperature for the whole state being lower than for any similar period since the records of the United States Weather Bureau were begun. According to the Climate and Crop Service of the United States Weather Bureau, the ground was frozen and covered with snow throughout the month. In the drainage basin of the Black River an unusual amount of snow fell even for that remarkably cold and snowy section.

The intense cold which characterized the early part of December abated for nearly a week in the latter part of the month. Beginning with the 20th, the temperature rose every day above freezing at Lowville until the 26th. On the 20th there was a fall of .73 inch of rain at Lowville and .85 at Number Four. This was accompanied by a warm south wind. In the five days, December 20–24, 1.5 inches of rain, or its equivalent of snow, fell at Lowville, and in the three days, December 19–21, the fall at Number Four was 1.31. An excessively cold snap then followed and lasted throughout the month.

A large amount of water was washed from the snow-covered hillsides and banks of the streams by these rains and thaws. Sewers were flushed and ice in the vicinity of the sewer outlets was melted and carried off. According to records made by the Division of Hydrography of the United States Geological Survey, the discharge of the Black River at Felt's Mills, seven miles above Watertown, rose from about December 20. The rise was rapid and continuous until December 25, after which the flow diminished with slight remissions until January 9, 1904.

The source of the infectious matter. About a month after the outbreak of the epidemic, there were sent out a number of inspectors to determine, if possible, whether any cases of fever had occurred which could have led to the contamination of the water supply with typhoid germs. The search extended along the banks of the Black River as far as Carthage. One of the inspectors, Mr. W. E. Fuller, in a communication to *Engineering News*, March 3, 1904, page 205, has recorded what was found up to the latter part of February, 1904.

Going up stream from Watertown, the nearest cases of typhoid

FIG. 1. Carthage, from the West Side of the River.

FIG. 2. West Carthage, from Carthage. A sewer discharges under the further end of the bridge. This is eighteen miles above the intake of the Watertown Water Works.

were found at Black River, about 4½ miles above the intake of the water works. Five cases existed there: the first started during the latter part of December and the other four began in the first half of January, 1904.

No cases of typhoid were found in the next two villages, Great Bend and Felt's Mills.

At Deferiets, where there was a sewerage system emptying into the river about 10 miles above the intake of the Watertown water works, there was a small epidemic of typhoid at about this time. One case had occurred in September, 1903, a second in the first half of December, two more in the second half of December, and twelve in January and February. Deferiets has a population of about 500.

At the twin villages of Carthage and West Carthage, about seventeen miles above the water works, fifteen or sixteen cases of typhoid were said to have occurred from September to February. These villages are not provided with public sewers, although several private sewers empty into the river.

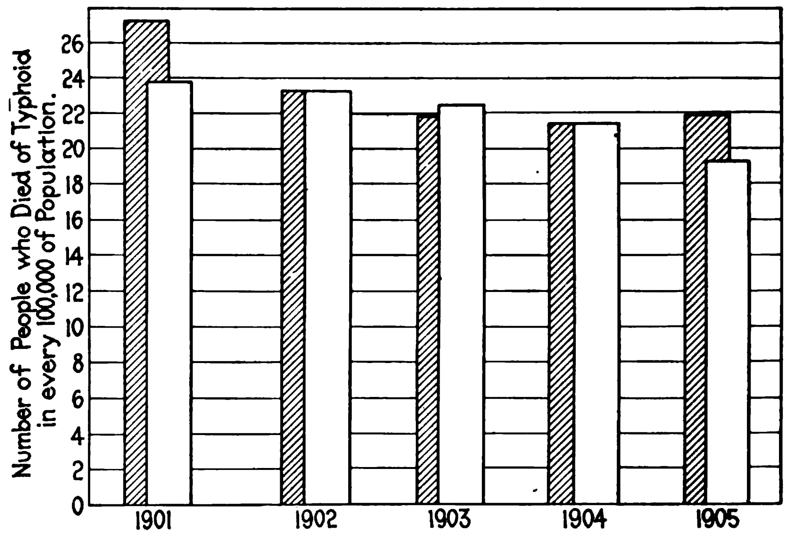
It thus appears that typhoid had existed at more than one of the villages between Watertown and Carthage before the outbreak at Watertown. How far typhoid had been prevalent in the thirty or forty settlements or villages on the drainage area above Carthage is not, and never will be, known.

Apparently there was within this watershed what has occurred in many other river valleys,— an epidemiological wave of typhoid. It is not difficult to understand how these waves occur. When typhoid is introduced at any point, the infectious matter gets into the water courses, which are, of course, the natural sewers of the country. As the sewers of one town become the water supplies of others, the disease is transmitted by the water down the valley in the direction of the flow of the stream. To some extent there is also an upward, downward, and lateral transmission of the disease, due to movements of the population and the transportation of milk from one village to another.

With a whole valley infected with typhoid, as was the valley of the Black River at the time of the Watertown epidemic, it is plain that the lower parts of the river are likely to become very heavily contaminated with typhoid germs and, owing to the numerous

points of pollution, may remain so for a long time. We have under these circumstances not an example of a sudden, intense, and brief contamination such as produce the most sensational explosions of typhoid, but a more continuously operating cause and a corresponding continuous effect. Instances of epidemics of this type have frequently been afforded by cities which draw their water supplies from large rivers. The statistics of the Watertown epidemic, although admittedly imperfect, seem to indicate that the public water supply of the city may have been contaminated in this manner.

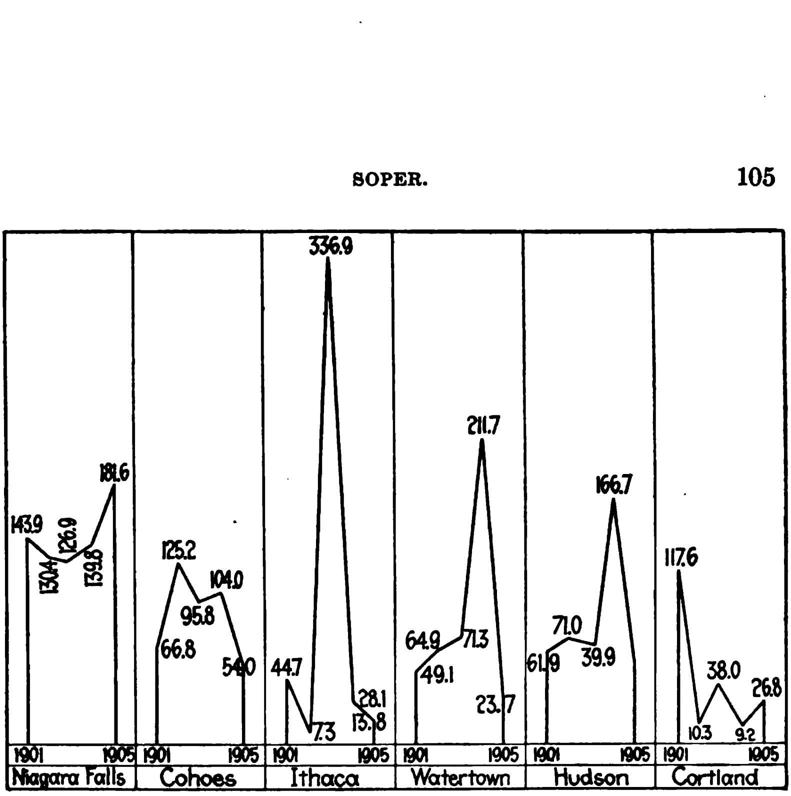
Judging from the fact that many cases of typhoid occurred at Black River and Deferiets at about the time that the epidemic began at Watertown, it is barely possible that there was one large common source of germs which supplied all these places. In other



Among every 100,000 Inhabitants in New York State there Died of Typhoid Fever in the Years:

	1901	1902	1903	1904	1905
In Cities of over 8,000 Population ▭	23.8	23.2	22.3	21.3	19.1
" Places " less than 8,000 Population ▨	27.2	23.2	21.8	21.3	21.8

FIG. 6. Comparison between Rural and Urban Typhoid Death-Rates in New York State for Five Years, showing that in the year of the Watertown epidemic, typhoid was not unusually prevalent in city or country districts.



Cities of New York State in which more than 100 People Died of Typhoid, for every 100,000 of Population in some Year between 1901-5 incl.

FIG. 7. Comparison between the Records of the Six Cities in New York State which had the Greatest Number of Deaths from Typhoid between the Years 1901 and 1906. According to the average rate, Watertown occupied fourth place; according to the rate for each year, Watertown was second.

words, it may be that the infectious matter which caused the Watertown epidemic originated above both Deferiets and Black River.

On the other hand, the germs which produced the Watertown outbreak may have come exclusively from some nearby point, such as Deferiets.

Setting aside this interesting but uncertain element as to the exact origin of the germs, the fact is clear that the epidemic at Watertown came from the public water supply.

The outbreak and course of the epidemic of 1904. According to the testimony of physicians, there had been an unusual amount of diarrheal disease in Watertown during the fall and early winter of 1903–4. During November and December typhoid fever had been much less prevalent than usual at this season of year. From

the reports of physicians made to Dr. E. S. Willard, health officer of the Board of Health of Watertown, it appears that the number of cases of typhoid for November was 7. In December the number reported was 15. On January 1, 8 cases were reported, and on the 2d, 13. In the following few days the number of new cases reported each day varied from 1 to 13. On January 15, 23 cases were reported. The newspapers now announced an unusual prevalence of typhoid, and, suspecting that the public water supply was to blame, the people were advised by the mayor to boil the water which they used for drinking purposes. The cases were widely scattered through the city.

The daily incidence of cases during the first few weeks is not clearly known, nor in fact are the dates of onset of the cases accurately established for any part of the outbreak. It was not customary for physicians to report their cases of typhoid with regularity before the epidemic and they did not do so afterward.

To a sanitarian unfamiliar with the peculiar conditions which occur in typhoid epidemics the failure of physicians to report their cases seems inexplicable if not inexcusable. The fact is, however, that physicians are extremely busy at such times in attending to the pressing needs of the sick, and are sometimes called upon to spend so much time in ministering to their patients that they feel unable to allow themselves proper time for sleep or meals. Often several visits are necessary before the nature of the sickness can be discovered. When a patient is at last found to be suffering from typhoid the date of onset may be forgotten. The full name and exact address of each patient is rarely known to an attending physician. To expect that every case of typhoid will be promptly and satisfactorily reported, therefore, is unreasonable, however desirable such reports may be from the public health standpoint. For a board of health to get even fairly satisfactory returns generally requires much telephoning, interviewing, and circularizing and sometimes a house-to-house canvass.

After the board of health work became systematized, each case reported was tabulated on two sets of cards. One of these sets was then arranged alphabetically according to the names of the patients and one set according to the street addresses. The sanitary circumstances surrounding each case were carefully inves-

tigated by the Board of Health and records kept of the principal points of information ascertained in connection with it. Many errors in the returns were corrected in this way. The genuine cases of typhoid were finally spotted on a large wall map and placed on a chart. In the stress of the hour some cases were probably overlooked by the physicians and the exact dates of others accidentally misstated. Some cases were reported several times and the addresses were frequently wrong. Some cases of disease other than typhoid were reported as typhoid. A curve plotted from the corrected returns in the possession of the Board of Health shows, as such curves always do, large numbers on some days and almost none on days immediately preceding and succeeding these. It is practically certain that people do not fall sick during typhoid epidemics in this extremely irregular way.

In the hope of eliminating some of the errors in the records, I have taken as an approximation to the probable number of cases each day an average of the number of cases for three days — the day before, the day itself, and the day after the date on which the number of cases is desired. The corrected returns and these averages with averages for each five days are given in Table IV. From these data I have plotted curves to give some idea of the progress of the epidemic. (See Fig. 8.)

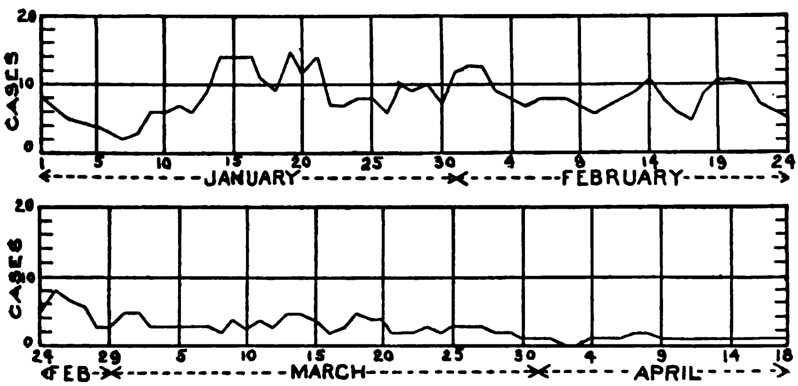


Fig. 8. Progress of the Epidemic of 1904. The Board of Health campaign was started about February 22. The upper curve represents the course of the epidemic before, and lower curve its course after, the repressive measures were put in force.

TABLE IV.

CASES OF TYPHOID FEVER AT WATERTOWN, N. Y., FROM JANUARY 1, 1904, TO APRIL 18, 1904.

Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.	From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904			1904		
January 1	8	10	January 31	6	12
„ 2	13	7	February 1	22	13
„ 3	0	5	„ 2	10	13
„ 4	1	1	„ 3	8	9
„ 5	2	2	„ 4	8	8
Total	24	25	Total	54	55
January 6	3	3	February 5	9	7
„ 7	3	2	„ 6	4	8
„ 8	1	3	„ 7	12	8
„ 9	4	6	„ 8	7	8
„ 10	13	6	„ 9	5	7
Total	24	20	Total	37	38
January 11	1	7	February 10	8	6
„ 12	7	6	„ 11	5	7
„ 13	10	9	„ 12	9	8
„ 14	9	14	„ 13	9	9
„ 15	23	14	„ 14	10	11
Total	50	50	Total	41	41
January 16	9	14	February 15	13	8
„ 17	10	11	„ 16	1	6
„ 18	14	9	„ 17	5	5
„ 19	4	15	„ 18	9	9
„ 20	26	12	„ 19	12	11
Total	63	61	Total	40	39
January 21	7	14	February 20	13	11
„ 22	8	7	„ 21	7	10
„ 23	5	7	„ 22	10	7
„ 24	8	8	„ 23	3	6
„ 25	11	8	„ 24	6	5
Total	39	44	Total	39	39
January 26	6	6	February 25	6	8
„ 27	8	10	„ 26	12	7
„ 28	15	9	„ 27	3	6
„ 29	5	10	„ 28	3	3
„ 30	10	7	„ 29	3	3
Total	44	42	Total	27	27

TABLE IV.—*Continued.*

Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904				1904			
March	1	8	5	March	26	5	3
"	2	5	5	"	27	2	3
"	3	2	3	"	28	3	2
"	4	2	3	"	29	1	2
"	5	4	3	"	30	1	1
Total		21	19	Total		12	11
March	6	4	3	March	31	2	1
"	7	2	3	April	1	0	1
"	8	3	2	"	2	0	0
"	9	2	4	"	3	1	0
"	10	6	3	"	4	1	1
Total		17	15	Total		4	3
March	11	1	4	April	5	0	1
"	12	4	3	"	6	1	1
"	13	3	5	"	7	2	2
"	14	8	5	"	8	2	2
"	15	3	4	"	9	1	1
Total		19	21	Total		6	7
March	16	0	2	April	10	0	1
"	17	3	3	"	11	2	1
"	18	4	5	"	12	0	1
"	19	7	4	"	13	0	1
"	20	2	4	"	14	2	1
Total		16	18	Total		4	5
March	21	2	2	April	15	0	1
"	22	2	2	"	16	0	1
"	23	3	3	"	17	2	1
"	24	3	2	"	18	1	1
"	25	1	3	Total		3	4
Total		11	12	Grand total,			595

There is little doubt that the epidemic broke out about January 1, although it was not investigated until over a month later. The daily increase in the number of cases was apparently rapid up to about January 20, when there was a slight decrease until the 25th,

followed by another increase which lasted until about Feburary 1. The daily number of cases then declined slowly and remained comparativelv constant between February 9 and 25. After this there was a considerable reduction. The epidemic may be considered to have ended April 18. It had run 110 days.

The total number of cases of which I have reliable record was 595. The number of deaths to May 1 was 44. The case fatality, based on these figures, was 7.4 per cent.

Subsequent to April 18, 102 cases were reported up to January 1, 1905. The number of deaths from typhoid, in addition to those already mentioned, was 3 up to January 1, 1905. Since 1904 the number of cases and deaths from typhoid reported at Watertown have been as follows: 1905, 108 cases, 6 deaths; 1906, 130 cases, 13 deaths; 1907, 103 cases, 10 deaths.

When the cases of typhoid were spotted on a map it was seen that the fever had visited every part of the city. (See Plate V.) The poorer sections suffered most, and the aristocratic parts least, a result which was largely accounted for by the fact that the poorer sections were the most crowded and there were consequently more people to be attacked in a poor section on a given area. In the best residential quarters, also, more personal care was exercised to avoid the fever. The drinking water of many of the people was boiled or carefully filtered. Institutions, such as children's homes, and the jail, had their full share of typhoid.

There were some parts of the city which suffered to a greater extent than could be fully explained on the score of crowding and lack of personal precautions, and it seemed reasonable to conclude that some peculiarity of the distribution system of the water supply carried to these sections exceptionally large doses of infectious matter, or that insanitary conditions about the houses increased the people's chances of infection. No extensive local foci such as germ-infested wells were found, such as I had discovered at Ithaca. The people, as a rule, were in much better financial circumstances and lived more comfortably and there was much less typhoid transmitted from person to person than I had seen in the epidemic at Butler. Nevertheless, the fever was undoubtedly transmitted to some extent from person to person in spite of the utmost efforts of the Board of Health. The greatest danger in

this regard probably occurred when a patient was nursed at home. Under these circumstances the person who acted as nurse sometimes did the cooking for the rest of the family and, for convenience and warmth, the patient was occasionally nursed in a room close to the kitchen. As far as practicable these dangers were reduced to a minimum by the operations of the Board of Health.

IV.

MEASURES TAKEN TO CHECK THE EPIDEMIC.

At a meeting of the local Board of Health, held on February 1, it was decided to make an official investigation into the cause of the outbreak. It was fully realized that a serious epidemic was at hand. The health officer had notified the State Department of Health of the prevalence of typhoid under date of January 30.

State Action. On February 8 the health officer was empowered " to employ a sanitary expert at once to investigate the situation and take such measures as may be reasonable and necessary to eliminate the epidemic." In response to the information furnished the State Department of Health on January 30, Prof. Olin H. Landreth, consulting engineer of the State Department of Health, made the city a visit on February 13.

Professor Landreth caused a canvass to be made to ascertain the number and distribution of the cases and the date of attack in each case. He also advised that postal cards be sent to every family in the city, cautioning the people to boil the water used for drinking, for washing vegetables which were to be eaten uncooked, and for washing dishes, etc. Professor Landreth's suspicion rested upon the public water supply as the cause of the outbreak and he appointed canvassers to visit the settlements and shores along the Black River to search for any cause of typhoid which might have led to the contamination of the public water supply. At the same time data were collected which put the milk supplies out of question as the cause of the epidemic.

On February 20 Professor Landreth again visited Watertown. On this occasion the investigation which he initiated on his former visit was supplemented. Various sanitary measures were recommended and much salutary advice was given on sanitary matters.

Steps were begun toward cleaning and disinfecting all premises on the Black River where typhoid fever cases were found to have existed.

Other short visits were subsequently made to Watertown by Professor Landreth in his official capacity. On these occasions the need of extending the inspection and disinfecting work on the Black River drainage area were urged. But the city was less interested in cleaning up the drainage area than in attending to sanitary work within its boundaries. Eventually, by mutual consent, the direction of the work on the drainage area was placed wholly in Professor Landreth's hands, the city of Watertown agreeing to coöperate with the State Department of Health to the extent of paying the cost of this work.

Unable to secure from the state an expert who could give his undivided time to the work of checking the epidemic, and believing that the situation required such attention, the Board of Health engaged me for this purpose.

Plan of the campaign carried on by the city. A sanitary campaign was planned with the double object of checking the epidemic and restoring public confidence. Much of the work was based on my experience in the typhoid epidemic at Ithaca, N. Y., where I acted as the official representative of the State Board of Health and initiated through the local Board of Health an active campaign against the fever. I had been called to the Ithaca work, apparently, because I had had some experience with typhoid when I was the sanitary engineer of the New York City Department of Health.

The measures for controlling the epidemic which were carried out at Watertown during my connection with the city were largely based on the results of Koch's now famous studies at Trier, and the opinion which had grown out of my experience, that typhoid is not only infectious, but contagious, and transmissible from person to person.

The immediate objects of the campaign were the prevention of infection through the river water and from cases of typhoid already in the city. It was accepted by me as abundantly proved that the water supply had given rise to the original cases.

I advised that every typhoid patient be sent to hospital or

strictly isolated at home. No patient should be discharged from medical care until bacteriological tests showed that his excretions were no longer dangerous. All mild and suspicious cases of fever should be treated like typhoid. Secondary sources of disease, such as contaminated wells and milk supplies, were to be guarded against. All infectious matter should be destroyed by disinfection at its source. It was not practicable to put all these measures into effect; at least, not at once; nor ever with that completeness which was desirable. They were, nevertheless, kept always in mind and give the key to the principal work which was done by the Board of Health during my connection with it.

The sanitary work of the inspectors acting under the direction of the State Department of Health on the drainage area of the Black River and the natural flow of the river during two months of time seemed to me to have been sufficient to have removed every source of danger from the public water supply which it was practicable to remove. Still, in order to obtain the greatest measure of safety procurable, various steps were taken to secure protection from the public water supply. The distributing mains were flushed from the hydrants, one section of the city being taken at a time, and the work done in a thorough manner. The people were urged to continue to boil that portion of the water which it was necessary to use for drinking, dish-washing, and other purposes which might, by any possibility, lead to infection. The builders of the filtration plant were requested to push the completion of their work so that the plant could be made available at the earliest date.

Spring water supply. A supply of drinking water from springs of proved purity in the outskirts of the city was established and the water peddled from house to house at the nominal cost of one cent per gallon to the consumers. The price received for this water did not quite cover the expense of supplying it, but the outlay was trifling compared to the benefits received. As I had found in the epidemic at Ithaca, the distribution of spring water was greatly valued by the people.

To bring the water from the springs and deliver it from house to house a number of tank wagons were built. The tanks were made of galvanized iron of cylindrical shape. The capacity of these

tanks varied from 100 gallons to about 400 gallons each. They were filled through an opening at the top which was large enough to admit apparatus for cleaning. Each tank was sterilized at least twice a week with steam from a large paper mill in the central part of the city. The quality of the water was determined by daily analyses made from samples taken from the delivery wagons. The water was drawn from the tanks by means of large faucets.

At one time ten wagons were required to supply the demand for water. To facilitate the sale of the water, tickets were sold in quantity; these were exchanged by the water peddlers for the number of gallons wanted at each house. The tickets were used but once. The wagons followed fixed routes laid out on maps. Most of the city was covered in this way three times a week.

Examination of wells. Lists were made of the wells situated on private premises and on business property and arrangements were made to examine these waters. This examination consisted of, first, an inspection to determine the kind and depth of the well, its location with reference to houses, stables, and privies; the nature of the soil, and other points which would aid in interpreting the data obtained from an analysis of the water. At a later date a representative of the Board of Health visited the well and collected a sample of the water in a sterilized bottle. This sample was generally analyzed within four hours. It was examined for chlorine, hardness, number of bacteria, and the presence of coli by the presumptive test. An opinion was drawn from the results of the analysis and the record of the inspection and this opinion was then communicated to the owner of the well by postal card. Some wells were examined several times. Most wells were of unsatisfactory quality. It was necessary in a few cases to condemn and order wells closed. This was always done after a full discussion of the circumstances before a formal meeting of the Board of Health, the well being provisionally closed from the time when its condition was first determined.

Hospital arrangements. Owing to the unusual number of patients requiring to be accommodated, and the limited amount of space available for them, the two regular city hospitals were, at the height of the epidemic, greatly overcrowded. The City Hospital with forty regular beds had sixty patients. A hospital

operated by an order of Sisters of Charity, with thirty-five beds under normal conditions, was caring for fifty patients. The insanitary conditions which generally obtain in overcrowded fever hospitals were unmistakably exhibited in both of these institutions. A succession of cases of a peculiarly malignant form of erysipelas, generally accompanying typhoid, occurred in the City Hospital and in the Sisters' Hospital. Neither hospital had proper means of isolating cases of contagious disease. It therefore became necessary for the Board of Health to make arrangements for the accommodation of erysipelas and typhoid cases elsewhere. This work was done with the utmost dispatch.

Through the cordial coöperation of the Department of Charities, the headquarters of the Department on Massey Avenue were vacated and quickly made available for the erysipelas patients.

In preparing this house for its new use, every movable article was first taken out. The floors were then cleaned and painted,

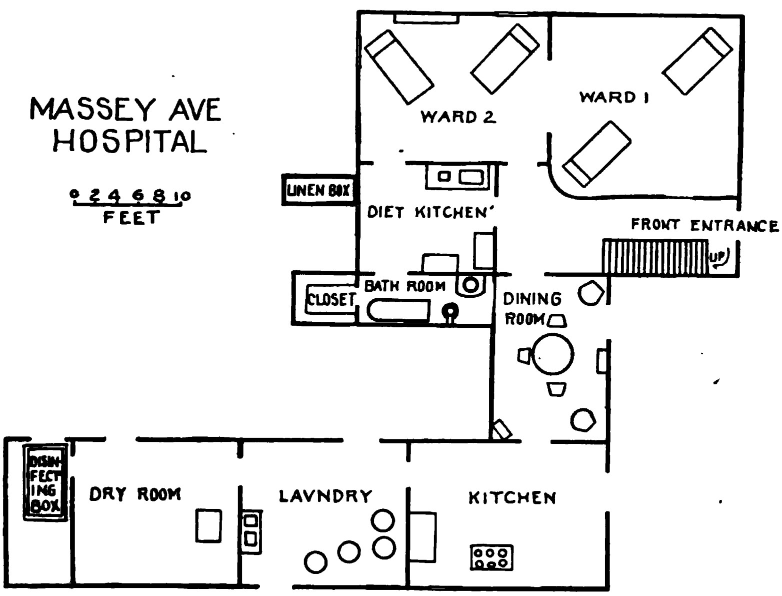


FIG. 9. Temporary Hospital on Massey Avenue opened for the Care of Erysipelas Patients, chiefly sent from the Overcrowded Permanent Hospitals of the City.

the plumbing overhauled, a disinfecting chamber large enough to contain a double mattress was constructed, a laundry was fitted out, and the house was furnished with high beds and all other appurtenances of a first-class temporary hospital. (See Fig. 9.)

In drafting the hospital regulations for this house, three general principles were kept prominently in mind: First, every part of the building was to be kept in a state of surgical cleanness. Second, no excretions, bedding, food, clothing, or other possible source or vehicle of infection was to leave the building, or the ward, if that was practicable, without disinfection. Third, every window and door was to be kept open as much as possible, and the patients, protected by screens, were to be given as much fresh air as they and their attending physicians would permit.

The results were entirely satisfactory. The disease did not spread to any of the attendants or nurses as had been the case before this temporary hospital was opened. Eleven severe cases of erysipelas were treated in this hospital. Seven were complicated with typhoid fever. The majority were in an advanced stage of the disease when admitted. One patient died. The rest recovered.

In order properly to care for the typhoid fever patients who could neither be accommodated at the permanent city hospitals nor isolated satisfactorily at their homes, a special typhoid hospital was opened. Much difficulty was experienced in finding a suitable building for this purpose. It was finally decided to use a new high school building which had just been completed at a cost of about $100 000, but not yet equipped with school furniture. Serious objection to this proposition was made by the Board of Education, but the health authorities decided that its conversion into a hospital was a necessary step and took temporary possession of the property.

The class rooms on the main floor of the school building were divided into male, female, and children's wards. A surgical ward was equipped and kept ready for emergency in case operations for perforation became necessary. Each patient had a minimum of 64 square feet of floor space and 770 cubic feet of air space. Separate rooms were reserved for patients who were very sick. Diet kitchens with gas stoves and instantaneous water heaters were established in the main hallways. Accommodations for the nurses

were provided on the second floor. A kitchen, a dining room, and a laundry were arranged in the cellar; later, the dining room and kitchen for the nurses and attendants were moved to the top floor. (See Fig. 10.)

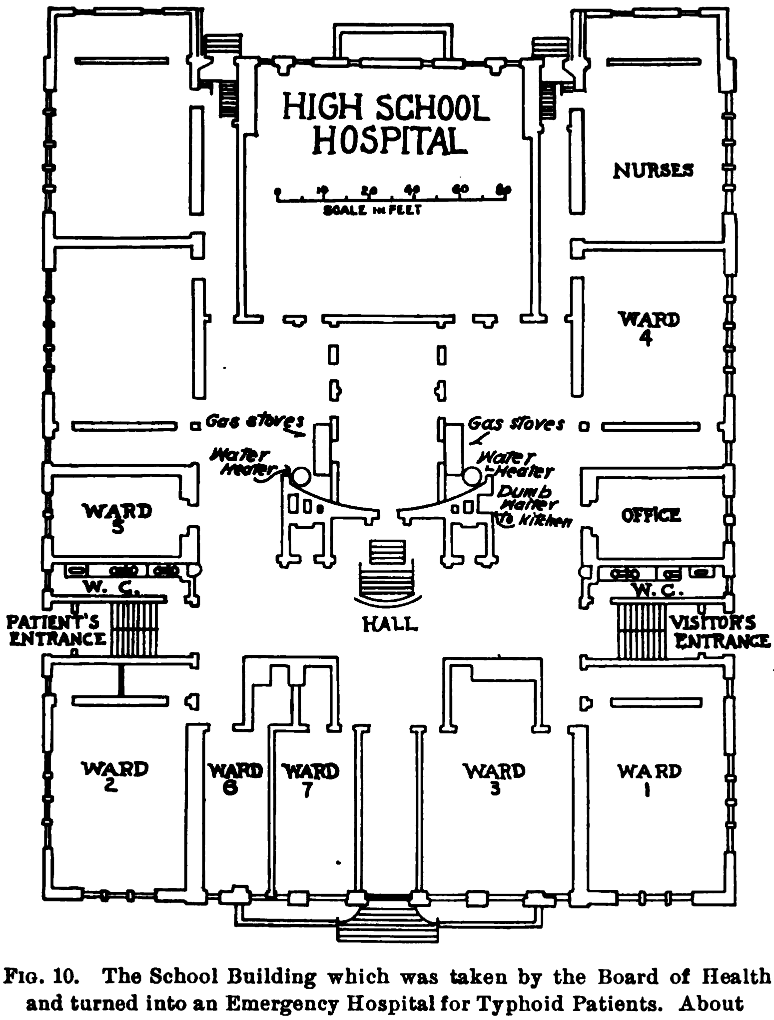


FIG. 10. The School Building which was taken by the Board of Health and turned into an Emergency Hospital for Typhoid Patients. About one hundred patients were treated. No case of typhoid occurred among the nurses, doctors, or attendants.

Rules and regulations for the management of this hospital were drafted on similar lines to those adopted for the erysipelas hospital, but they were less severe. Abundance of air in all parts of the building, thorough cleanliness in the wards, halls, closets, and nurses' dormitories, and prompt disinfection of the excretions and articles possibly contaminated with the excretions, and skillful nursing were the principles most insisted upon.

The disinfectants used were fresh milk of lime for the stools and urine, and 1 to 1 000 bichloride of mercury solution for cloths, hands, and floors. Sheets, pillow cases, and the garments of the patients, when removed, were placed in cloth bags at the bedsides and taken at once to the cellar where they were disinfected and washed. Sputum and cloths soiled with excreta, urine, or sputum were put into paper bags at the bedsides and removed in iron ash cans to a furnace in the building and burned. The cups, dishes, spoons, and other articles used in feeding the patients were kept separate for each case and regularly sterilized by boiling. The floors of all the wards were mopped with 1 to 1 000 bichloride each day. No sweeping was permitted in any part of the building. Care was taken to avoid the production of dust, by the use of damp cloths. No receptacles for milk or water were allowed to leave the building. The hospital was furnished with a fresh supply of spring water daily.

Dr. Philip C. Washburn, a graduate physician, was placed in charge of the hospital. Dr. Washburn slept in the building and was thus able to render prompt and valuable emergency aid on several occasions at the bedsides of the patients. Fortunately, no surgical operations were required. Besides Dr. Washburn, Drs. Spencer and Bibbins, prominent members of the medical profession in Watertown, kindly volunteered to serve as official medical consultants in case of need. The presence and advice of these gentlemen in connection with the medical care and nursing of the patients proved to be of great value.

None but picked graduate nurses was employed at either of the two hospitals conducted by the Board of Health. With a single exception they proved themselves capable, conscientious, and unfailing in the performance of their duties. The total number of nurses employed was 22, of which 17 were connected with the High School hospital and 5 with the erysipelas hospital.

FIG. 1. Massey Avenue Temporary Hospital, used for Erysipelas Patients. Strict isolation and disinfection were practiced. No one contracted erysipelas from these patients after they were brought here.

FIG. 2. New High School on Sterling Avenue, used as an Emergency Hospital for Typhoid Patients. About one hundred patients were treated here, mostly on the first floor.

The number of typhoid patients treated at the High School hospital was 97. There was but one death. None of the employees contracted the fever.

The expense of equipping and maintaining the hospitals was borne by the city. Each patient or his friends was expected to pay what he could afford for the nursing and care which the city provided, reckoned on a basis of $4.00 per week. Medical attendance was extra, and, except in indigent cases or emergencies, was provided by the patient or his family. Any physician in good standing was permitted to send and attend cases of typhoid at this hospital. For the removal of the patients from their homes, a specially constructed ambulance was provided without charge.

It is impossible to refrain from referring to the valuable help given by the ladies of Watertown in fitting out these two hospitals. Much help in the way of purchasing supplies, sewing, and aid of a kind that men cannot give was contributed by them with a promptness and generosity which added much to the success of the undertaking.

The bacteriological laboratory. A bacteriological laboratory was established for the analysis of water, milk, blood, urine, and other work in connection with the suppression of the epidemic. All the apparatus was of the best quality and purchased new. Dr. Herman Requi, of the University of Chicago, was placed in charge of the laboratory and was given enough help to enable him to turn out prompt and accurate reports. The work of this laboratory was done at the expense of the city and without charge to any individual.

Widal examinations to assist in the diagnosis of suspected cases of typhoid fever were given first place in the routine of the laboratory. No limit was placed upon the number of examinations which would be made for any physician or patient. If a specimen of blood reacted negatively, the physician who sent it was advised to furnish another specimen from the patient at a later date.

As I had found elsewhere, the only practicable way to obtain many specimens of blood for the Widal test was in the form of drops of blood dried on cards. Several races of typhoid and typhoid-like bacilli were kept in culture and were used when the

ordinary typhoid bacillus failed to agglutinate in proper dilution with the serum dissolved from the dried blood. Up to April 21, there had been examined 251 samples of water, 98 specimens of blood, and 95 specimens of urine.

Board of Health disinfectants. Disinfection was practiced in several ways. At the outset an effort was made to introduce uniform methods of disinfection in as many of the fever houses as possible. Because of the unreliability of the proprietary disinfectants sold in the shops, the Board of Health established a central disinfectant bureau and from this point distributed, without cost to the consumers, disinfectants throughout the city. Several wagons were employed to carry freshly slaked lime and concentrated bichloride of mercury to each house in which a case of typhoid fever was known to exist. Every fever house was thus visited twice a week, sometimes oftener. The disinfectants which were sent out on the wagons were known as "white fluid" and "blue fluid," and were of such concentration that, upon adding to either four times its volume of water, it would be of proper strength for use. The milk of lime, or white fluid, when ready for use, was composed of one part of freshly slaked lime to eight parts of water. The bichloride of mercury solution employed consisted of one part of bichloride of mercury to one thousand parts of water; this was made acid with hydrochloric acid and colored blue with common washing bluing. Directions for using both of these disinfectants were printed in large type on stout sheets of cardboard and left at each house where the disinfectants were employed.

Fumigation with formaldehyde was performed by the Board of Health at each house after a case of fever unless there was good reason to believe that this precaution was unnecessary. The method of generating the formaldehyde first used was that regularly employed by the Watertown Board of Health. It consisted in the use of a lamp with paraform pastils from which the gas was expelled. Later, because of the large number of houses which needed to be fumigated, a more rapid method was adopted. After the room had been closed as air tight as possible, and rugs, draperies, bedding, and other similar articles had been hung on chairs or suspended in the middle of the room, a large sheet was hung up. From a small watering pot there was then poured upon this sheet

a solution of formalin of 40 per cent. strength, in the proportion of at least 3 pints for every 1 000 cubic feet of air space, not allowing for the space taken up by the furniture and other articles in the room. After twenty-four hours all the windows were opened and the place thoroughly ventilated for at least two days. A careful scrubbing of the woodwork with soap and water and a brushing of the upholstery and drapery followed.

As a test of the efficiency of the fumigation, threads freshly impregnated with typhoid bacilli from twenty-four hour broth cultures were exposed in the room during the vaporization of the formaldehyde. After the disinfection the threads were immediately placed in sterile broth in the laboratory. If there was no growth this was taken to mean that the fumigation had probably been sufficient to destroy such bacilli of typhoid as may have been in the room as a result of its occupancy by the typhoid fever patient.

Other sanitary measures. The steps thus far described were the principal ones taken to prevent the spread of the fever, but they were not all. In many other ways the Board of Health endeavored to check the epidemic. The physicians were urged to report their cases accurately and promptly, and if they did not all comply, it was less the fault of the local board than to the neglect of this custom which commonly prevails in American cities.

Complaints of alleged nuisances were diligently investigated, and an effort made to have all houses and back yards put in order. The regulations of the Board of Health were revised, collated, and digested. The questions of garbage collection and disposition were studied, and the existing and other possible means of disposing of household wastes were inquired into.

Learning that smallpox existed in the vicinity of Watertown, an isolation hospital on the outskirts of the city was kept especially for the reception of patients suffering from this disease. Fortunately, it was not needed, but in anticipation of an emergency it was overhauled, cleaned, and put in readiness.

The sanitary awakening which resulted from the epidemic was the more remarkable from the fact that Watertown had been, in spite of its long and sinister typhoid history, a more than ordinarily well-regulated city.

Coöperation received in the sanitary campaign. As soon as the Board of Health began active work for the control of the epidemic, gratifying evidences of coöperation became apparent in many directions. The hospital authorities asked the board for help in difficulties connected with the overcrowded conditions of the hospitals, and offered such aid as they could give in other directions. Requests came from the press and the pulpit for interviews and addresses on sanitary topics. Organizations, corporations, and private citizens tendered their services and desired to be instructed in ways in which they might be of assistance in the general sanitary campaign. It was thus comparatively easy to carry to the people a knowledge of those principles of sanitation which were peculiarly applicable to the situation.

In endeavoring to give the instruction desired, particular emphasis was placed upon the value of simple but thorough methods of cleanliness and order, indoors and out. It was early pointed out that it was desirable that the storm doors and windows which had closed many houses from the outer air during the whole of the long, severe winter be removed as soon as possible. As the spring advanced, the people were advised to begin their annual house-cleaning early and make the work more than ordinarily thorough. Improved methods of collecting and disposing of the wastes so produced were undertaken by the city.

On the educational side, conferences were held with the physicians who practiced in Watertown and vicinity, and addresses were made before the local medical societies. The subjects dealt with on these occasions included the discussion of the nature and origin of typhoid fever; the paths and channels by which the infectious germs are communicated; the value of the Widal test; the importance of watching the urine for typhoid bacilli; the need and methods of eliminating typhoid germs from the urine when found; the necessity for sending to the Board of Health prompt and accurate reports of cases of typhoid fever; disinfection; the purification of water and sewage and the disposal of garbage and other municipal wastes.

From the first the physicians coöperated with the health board in a most encouraging and helpful manner. It is largely due to the help thus received that the work of the Board of Health was

successful and the number of cases of comrade or house infection was kept small.

The Chamber of Commerce and various other less prominent bodies entered cordially into the work. The Chamber, in fact, had been largely instrumental in causing the sanitary campaign to be undertaken.

The officers of the St. Regis Paper Company of Deferiets placed themselves under the direction of the Board of Health and carried out in the village surrounding their plant a careful plan to exclude infectious matter from continuing to enter their sewers which flowed into the Black River.

Charles F. Bingham, mayor; John B. Rogers, president of the Board of Health; Dr. E. S. Willard, health officer; and Mr. Theodore Ely Knowlton, representing the Chamber of Commerce, were indefatigable in giving personal attention to the work. To all the employees of the board credit is due for services of an unusually arduous nature; it is impossible to name all, but a special word of appreciation belongs to E. J. DeLong, principal office assistant.

DISCUSSION.

THE PRESIDENT. The paper is now before the Association for discussion. Perhaps Dr. Sedgwick will speak to us first.

PROF. WILLIAM T. SEDGWICK.* Mr. President and fellow members: It has been said repeatedly that the human race does not seem able to learn by recorded experience. It has got to suffer and learn by its own repeated and individual personal experience. And it seems to me that this epidemic wonderfully illustrates that point. The date of the epidemic was comparatively recent; and ever since 1885, when the great typhoid epidemic took place at Plymouth, Pa., it had been as clear as daylight to anybody that it was not wise to drink polluted water. Nevertheless, here was one of the proud cities of New York which continued to do that in full face of all the danger that must necessarily be connected with drinking it. It was apparently necessary for that city to sacrifice a lot of lives in order to be brought to the point of cleaning up its water supply.

There is nothing peculiar to Americans in this. It was the same

* Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

non-contagious and typhus comparatively contagious; and, as time went on, the idea was spread abroad, very naturally, that typhoid is not contagious, and physicians generally have thought so and have said so over and over again. Whereas, the truth is this: Typhoid is not as contagious as many other diseases, but it is truly contagious, nevertheless. It is a contagious disease, and it is a matter of satisfaction to me, and must be to every one who has treated it as such for a number of years, that some of us, at any rate, have said so, and were in print years ago as having insisted on that fact.

Now Dr. Soper, fortunately free from traditional prejudice in this matter, and following up the logical conclusions drawn from bacteriology, no doubt, has from the outset acted as if typhoid is practically a contagious disease, and as if the way to fight it is to treat it as such; and in his work at Watertown and at Ithaca and elsewhere he has honored the water-works profession, and the laity, of which he is a member, by having acted up to his convictions. Therein lies his distinction, because some of the rest of us who have known the facts, perhaps just about as well, have not so acted, or, at least, have not acted to the same extent. And I am glad he showed you in somewhat elaborate detail his hospitals of various sorts, and that he has told in his paper of the pains taken to disinfect and to get rid of infection. This is most honorable to him as an engineer and as a member of the water-works profession. In doing this he has actually led the way for boards of health to-day. It required a man like him to teach the Watertown board of health how to handle an epidemic of this sort. And the same thing was true in Ithaca, I believe, and elsewhere.

We have here the rounded whole. We have the clear proof of water infection; we have then the scientific and logical following through to the uttermost of the consequences of that conclusion, with insistence upon such a treatment of the epidemic as is required by our modern knowledge. The bacteriological progress which has been made, and especially certain discussions in Germany, have shown that it is easy to find the causal germ in early stages of the disease. And boards of health are beginning to wake up to the fact that typhoid has got to be treated in every respect as a contagious disease. Though admitting that it is not as con-

tagious as some other diseases, it is still to all intents and purposes contagious.

From another point of view, work of this kind tends to shed light upon that residual amount of typhoid fever which remains in a community after the water supply is perfected. In the case of Washington, for example, I have no doubt that it will eventually turn out, as the editorials in *Engineering News* have encouraged us to believe, that a large part of the typhoid fever still lingering there, after the water has been thoroughly purified, will prove to be spread by ordinary, old-fashioned contagion. All of which is important for us as water-works men. If typhoid fever in Washington remains high after a good filter is introduced, discredit falls perforce upon the filter. We need to know about this residual typhoid; we need to know what causes it, and if by proper disinfection and proper treatment, such as Dr. Soper has so very well outlined, we are able to reduce typhoid fever in any community to zero, or very nearly to zero, as I believe we shall be able to do when once these processes of disinfection have been installed, then the work will be of value not only as a lesson to boards of health, but as serving to protect those of us who are interested primarily in pure water. In more than one instance it has turned out that the purification of the water supply has not adequately diminished typhoid fever in the city affected, and one of the reasons is, apparently, a lack of this very thoroughness, this masterly grasp of details, which Dr. Soper has shown can be made effective, and which he was one of the first to display. It is for this reason, it seems to me, that the paper is of special value and of much timeliness, and I, for one, feel greatly indebted to Dr. Soper for his careful presentation of it here and now.

PROF. C.-E. A. WINSLOW.* Dr. Soper's account of the Watertown epidemic has interested me greatly and I am sure that others must feel, as I do, gratified that he should have reported his investigations through the medium of the New England Water Works Association. We have all of us grown to look with the pleasantest anticipations to Dr. Soper's visits to Boston, for he has always something to tell us which we want to hear.

* Assistant Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

The Watertown case as presented to-day appeals to me particularly as an indication of the new attitude which sanitarians are rightly adopting toward typhoid fever. Here is primarily a water-borne epidemic, and yet most of Dr. Soper's paper has dealt with preventive measures which have nothing to do with water supply. This means that the views which Professor Sedgwick and I had the honor to present to this Association in 1906 * have gained general acceptance to-day and that sanitarians now realize that water is only one factor in the causation of typhoid fever. In many communities this disease has no relation whatever to water supply, and even where polluted water is the prime cause, its influence is multiplied and extended by a host of other channels of infection.

The water-borne typhoid is easy to deal with. Cities which continue to drink sewage do so with their eyes open or in willful and deliberate ignorance. The factors which produce prosodemic typhoid, on the other hand, typhoid which spreads from person to person by various vehicles, are much more obscure and less easy to control. It is fortunate that in this particular case the authorities of Watertown atoned for their early neglect by prompt remedial measures after the epidemic of 1904. It is significant that in so doing they did not content themselves with retaining the ablest engineering talent in connection with purer water, but called in also our guest of the afternoon, who has made a national reputation as a specialist in the eradication of residual typhoid.

It is this prosodemic or residual typhoid which now constitutes the great bulk of the disease in the United States. Even in Watertown since the filtration of the water supply it still causes excessive death-rates, according to Dr. Soper's figures. Rates of 50 per 100 000 in 1906, and of 37 per 100 000 in 1907, demand some explanation. The truth is, we are only at the beginning of our knowledge of typhoid fever, in spite of the fact that probably no disease except tuberculosis has received so much attention. There is one factor in particular to which almost no attention has hitherto been paid, but which I am inclined to think is soon to receive a new share of attention, and this is the varying predisposition of the

* JOURNAL, March, 1906, Vol. XX, p. 51.

host. I should like to occupy a moment in calling your attention to this neglected point.

It is well known that typhoid fever, where not due mainly to polluted water, follows the curve of temperature with remarkable closeness. Recent investigations at Washington and at Youngstown, Ohio, have shown this with great clearness, and the phenomenon appears to be a universal one all over the world. Comparing different geographical areas, too, it is well known that typhoid on the whole is most prevalent in warm climates, but I did not myself realize how close this relation was until I analyzed, a day or so ago, the census returns for the Atlantic states according to their geographical position. As indicated in the table below, the typhoid rates for the white population average in the North Atlantic states about 30 per 100 000, and, with the exception of Pennsylvania, lie between 17 and 31; Pennsylvania's high rate of 44 is, of course, due to the large quantity of polluted water which was consumed in that state in 1900. The second group of states from Ohio to North Carolina shows an average death-rate of 54, and the individual rates range from 42 in Maryland to 76 in Kentucky. Finally the southeasterly and Gulf states show an average death-rate of 81, with individual variations from 57 in Florida to 93

TABLE V.

TYPHOID IN THE ATLANTIC STATES IN RELATION TO LATITUDE.

Death-rate per 100 000. Among whites only.

(United States Census for 1900.)

Northern Group.		Middle Group.		Southern Group.	
State.	Typhoid Rate.	State.	Typhoid Rate.	State.	Typhoid Rate.
Maine,	29	Ohio,	43	Tennessee,	84
New Hampshire,	17	Maryland,	42	South Carolina,	72
Vermont,	31	Delaware,	53	Georgia,	80
Massachusetts,	22	Dist. of Columbia,	69	Florida,	57
Rhode Island,	24	West Virginia,	62	Mississippi,	87
Connecticut,	27	Virginia,	48	Louisiana,	71
New York,	25	Kentucky,	76	Alabama,	93
Pennsylvania,	44	North Carolina,	70		
New Jersey,	21				
Group,	30	Group,	54	Group,	81

in Alabama. Of course such gross death-rates as these are affected by many other factors than temperature. The water supplies in individual cases are worse than in others, but on the whole I think there can be no doubt of the general lesson to be drawn from this table. Pennsylvania, with its heavily polluted water supplies, is found, it will be noticed, in the northern group, and the District of Columbia in the middle group. There seems no escape from the conclusion that there is a striking direct relation between temperature and the prevalence of typhoid fever.

In reviewing the question of seasonal prevalence in 1902, Professor Sedgwick and I were inclined to explain the autumn maximum as follows:

"The bacteriology and the etiology of typhoid fever both indicate that its causal agents cannot be abundant in the environment during the colder season of the year. The germs of the disease are carried over the winter in the bodies of a few patients and perhaps in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharges of these winter cases will depend, other things being equal, upon the length of time for which the bacteria cast in these discharges into the environment remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry to a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in nature of germs which proceed from previous victims of the disease."

My own confidence in the theory that the seasonal prevalence of typhoid is due to the effect of temperature upon the germ alone was somewhat shaken by a study of the admirable report upon the origin and prevalence of typhoid fever in the District of Columbia by Dr. Rosenau and his associates, published by the Hygienic Laboratory of the Public Health and Marine-Hospital Service. It appeared that in 1906 the typhoid curve did indeed follow in general the relation of the temperature, but that its greatest rise was not gradual but sharp, coinciding with the period of extreme hot

weather in the middle of July. The conception of the seasonal curve as due to the action of temperature upon the germ in the environment presupposes a very gradual change, and it is difficult to see how a sudden period of hot weather could produce a sudden reaction. If, on the other hand, the temperature affects typhoid incidence in part by a direct lowering of the vital resistance of the host, such a phenomenon might be expected. I have recently come upon striking confirmatory evidence of this latter theory. An extremely suggestive monograph on enteric fever in India has recently been published by Major Ernest Roberts of the Indian Medical Service (Calcutta: Thacker, Spink & Co., 1906). In this most important contribution to the etiology of typhoid fever, Major Roberts emphasizes his own belief in the importance of the vital resistance factor in the spread of typhoid. As he puts it: " Both host and parasite are definitely subject to the influence of the environment as it produces any seasonal changes; that both live and thrive by adaptation only; and that the problem of acclimatization or colonization is the same for both, — a contest for supremacy by immigrant races." The most striking evidence which Major Roberts adduces for the support of this view is included in the following table which shows that whereas the typhoid among the European troops in India follows the general rule and is concentrated in warm weather, that in the native troops follows an exactly reverse course. This seems difficult to explain on any theory of germ distribution. If germs are most abundant in warm weather they should affect both English and natives at that time. If, on the other hand, the relation of temperature to vital resistance of the host is a prime factor, we might expect just such a relation as is indicated in the table. Certainly English troops must be much more affected by the hot weather of India than the natives, and it is possible that the natives may in their turn be unfavorably affected by the colder season in many parts of the peninsula.

TABLE VI.

PERCENTAGE OF TOTAL MORTALITY.

	HOT SEASON. (May to Oct.) Per Cent.	COLD SEASON. (Nov. to April.) Per Cent.
European troops	62	38
Native troops	37	63

It seems to me clear that we have in the etiology of typhoid to reckon with three factors: First, the number of active germs present in the environment; second, the vehicles, water supply, milk supply, filth, etc., available for transmission of germs to the patient; and third, the vital resistance of the patient himself. It is perfectly possible according to this theory for an individual in good health to receive typhoid germs without succumbing to the disease, just as we know to be the case in tuberculosis and other disorders of the respiratory tract. A period of extreme hot weather, on the other hand, either by direct effect on the organism or through favorable indirect influence on fermentations in the digestive tract, upsets the defensive mechanism of the alimentary canal and we get a sudden sharp increase of typhoid fever. This, without in any way excluding the direct effect of temperature upon the germ in the environment, helps to explain the prevalence of fall fever and the increase of typhoid in warm climates. It helps also perhaps to explain the general excess of typhoid fever in this country as compared with that which obtains in northern Europe. It still remains true that a very large amount of the typhoid which exists in this country constitutes a national reproach. The prospects for the future, however, are bright and we may look to see residual typhoid wiped out in the future as water-borne typhoid is rapidly being eliminated to-day. When this is done it will be by just such forceful and thorough and painstaking campaigns as that which Dr. Soper has carried out at Ithaca and Watertown.

MR. GEORGE C. WHIPPLE * (*by letter*). The writer has been interested in reading Dr. Soper's paper, partly because of his general interest in the subject of epidemics and their relation to public water supplies, and partly because he is familiar with the present conditions in Watertown. From the facts which have been so ably presented many important lessons may be drawn. Some of these have been already mentioned by Professor Sedgwick and others. The more that epidemics of typhoid fever are studied, the more sanitarians are coming to appreciate the fact that this disease is contagious as well as infectious. In every large epidemic many of the cases, especially the late cases, are

* Consulting Engineer, New York City.

caused not by the original infection, but, as we say, by "secondary infection," that is, by direct contagion from early cases. This was strikingly shown in the typhoid fever epidemic that occurred in Gelsenkirchen, Germany, a few years ago. This epidemic was caused by an infection of the public water supply, but a careful study of the situation showed that a large proportion of the cases that developed near the end of the epidemic were due to contagion. This is interestingly shown by the following diagram, Fig. 11.

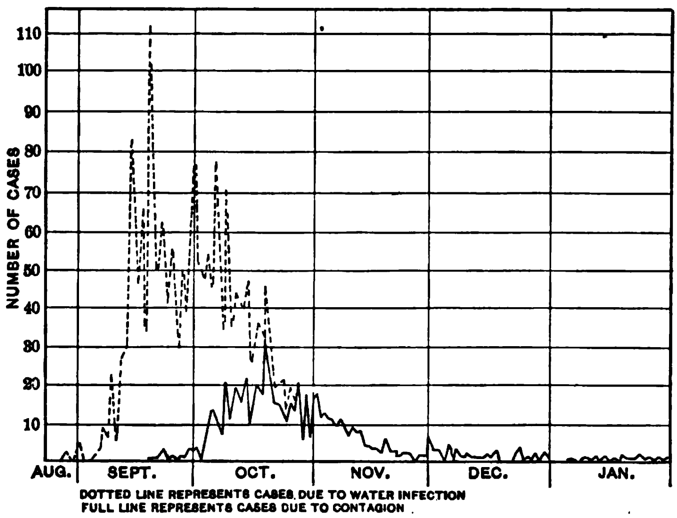


FIG. 11. DIAGRAM SHOWING THE PROGRESS OF THE TYPHOID FEVER EPIDEMIC IN GELSENKIRCHEN, GERMANY.

It was the prevention of these cases of secondary origin to which the work of Dr. Soper in Watertown was chiefly directed. How far he was successful in accomplishing the result cannot be definitely shown from the data presented, but there is no reason to doubt that many lives were saved by the sanitary reforms that were inaugurated under his direction.

It was unfortunate for the city that more stringent measures to quell the disease were not taken earlier in the history of the epidemic. The long duration of the epidemic shows that the water supply must have been in a continually infected condition for many weeks, as the city had but a small storage reservoir and

the water was pumped for most part directly into the mains. Apparently the measures taken to avoid the secondary cases were more elaborate and probably more effective than those taken to do away with the infection of the river water. The early history of the epidemic is an illustration of the procrastination which so frequently occurs even in the most intelligent communities. Apparently the epidemic had been running for nearly a month before any active measures were taken to get control of the situation. It would seem as if the occurrence of more than twenty cases during the first three days of January would have been followed by an immediate investigation. In these matters, however, the city of Watertown is not very different from other communities, nor can it be claimed that the officials were more lax than they are in most cities. In all health departments there is a tendency to regard the reported cases of infectious diseases as facts for history rather than as facts for prophecy. Such data are valuable for purposes of record, but they are far more valuable as indications of what is likely to happen in the immediate future. Unless the data reported by physicians are carefully studied from this point of view they lose a large part of their value.

Of the methods used by Dr. Soper in checking the epidemic little need be said, as they speak for themselves. The ways in which the typhoid fever germ is transmitted are now pretty well understood, and the methods of preventing these germs from finding their way from some patient to a new victim are pretty well known by water-works men, and have been the subject of repeated discussion in this Association. The writer is inclined to think that up to the present time too little attention, perhaps, has been given to the barriers that should be established to prevent the scattering of the germs from the patient; that is, to disinfection. The stamping out of this disease can only be done by coöperative work, in which physicians, nurses, engineers, and many others play a prominent part. In order to illustrate this fact the writer has made use of the simple diagram which is here presented, Fig. 12.

Mention has been made of the fact that a filtration plant was put in operation in Watertown in 1904.

Since the introduction of this filtration plant the typhoid fever

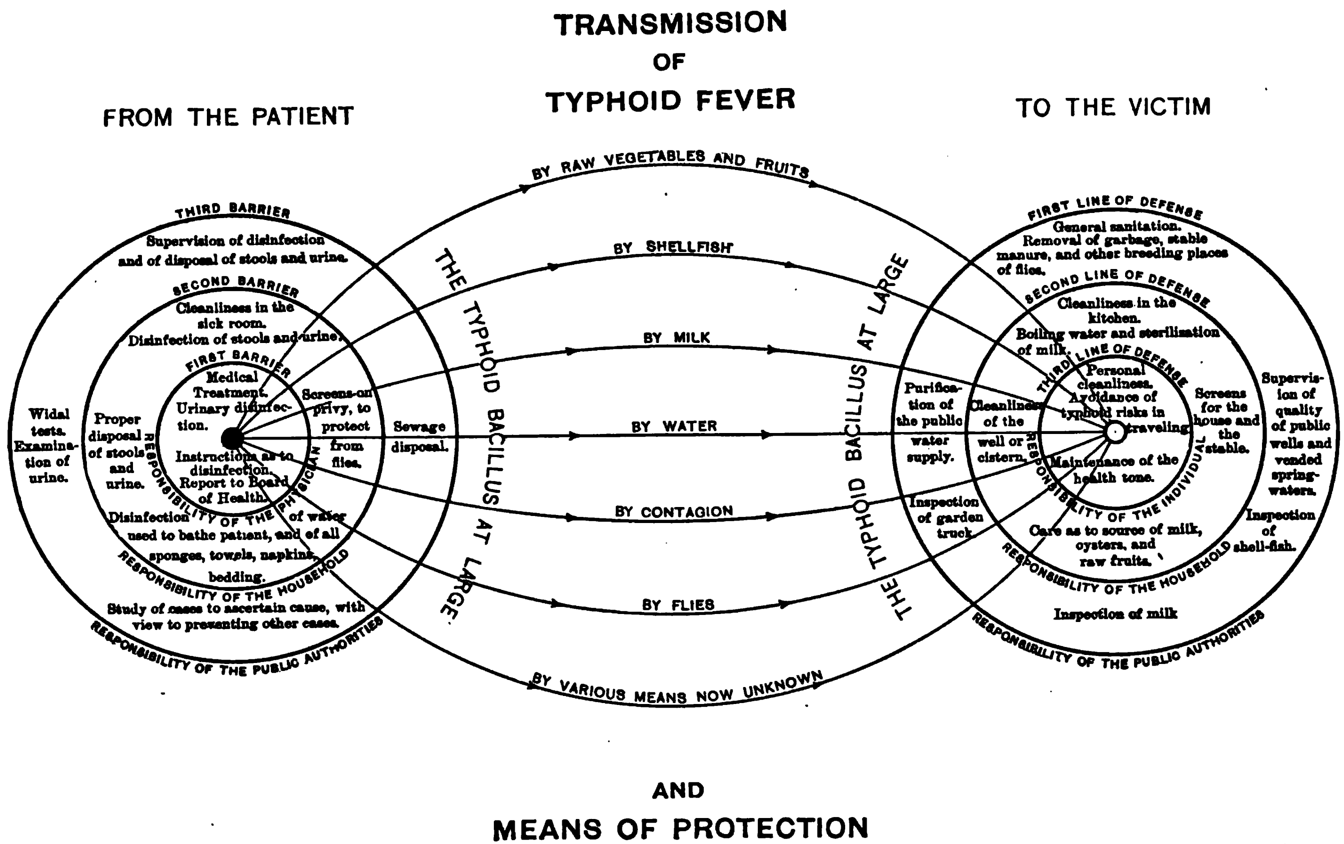


FIG. 12. (FROM "TYPHOID FEVER: ITS CAUSATION, TRANSMISSION, AND PREVENTION," BY GEORGE C. WHIPPLE.)

death-rate has been very materially decreased. It has not fallen quite as low, however, as it has in some other cities after the water has been subjected to purification. This has been due partly to the occurrence of cases apparently caused by contagion, as many of them were located near the outskirts of the city where there was no water supply; partly to the importation of cases that developed elsewhere; and partly, perhaps, to the existence of private water supplies for fire purposes in a number of mills that are connected with the city mains and provided with the usual check valves. The water for these fire supplies is taken from the river in the heart of the city and is obviously open to pollution. No direct evidence has been obtained that these mill supplies have been actually the cause of any cases of typhoid fever, but in view of the fact that such connections have caused trouble elsewhere, it cannot be denied that they are a source of danger, or that they may have played some part in the continuance of typhoid fever in Watertown. Certain it is, however, that the filter plant has shown a hygienic efficiency that compares well with similar filters elsewhere. The filter plant is in charge of a trained chemist and bacteriologist who very regularly and frequently makes analyses of the water before and after filtration. As this filter has not been described to the members of this Association I have taken the liberty of inviting Mr. F. H. Jennings, the chemist in charge of the plant at the present time, to contribute to this discussion a statement covering the operation of this filter since its installation in 1904.

Mr. F. H. Jennings * (*by letter*). It would be interesting to compare analyses of the Black River water as supplied to Watertown in the winter of 1903–4, if they were available, with analyses made subsequent to that time, especially the bacteriological analyses. The raw water counts obtained at the city filtration plant in Watertown in the months of December, January, February, and March show only moderate numbers of bacteria in the winters of 1904–5 and 1905–6, but much higher numbers in the winters of 1906–7 and 1907–8, as shown in the following table. The counts obtained in the summer months did not show a corresponding variation, though the counts obtained in the summer months

* Superintendent of Filtration Plant, Watertown, N. Y.

of 1907 were rather higher than in the preceding summers. At the same time, the positive presumptive tests for colon in one cubic centimeter samples of the raw water were more frequent in the winters when the counts were low than when they were high, averaging for the winter of 1904–5, 94.5 per cent., and for the winters of 1906–7 and 1907–8, 41.5 per cent. of the tests made.

TABLE VII.

BACTERIA IN BLACK RIVER WATER AT WATERTOWN, N.Y.

		1904.	1905.	1906.	1907.	1908.
January	Average		7 480	2 721	64 150	23 900
	Maximum		27 700	12 600	18 900	49 200
February	Average		2 200	2 033	21 410	40 800
	Maximum		4 920	5 000	52 600	138 300
March	Average		7 800	3 950	66 470	
	Maximum		30 900	17 000	134 100	
December	Average	2 960	708	39 800	30 480	
	Maximum	16 500	5 300	59 500	71 800	

A preliminary survey of the watershed made in the spring of 1907, covering sixty miles of the river above Watertown, in an effort to locate some specific cause of these higher counts, showed that they were general on the main stream and all the principal tributaries. During the winter of 1906–7 there was comparatively little snow, but during the winter just passed the snow was deep all over the Black River country. The general temperature was about the same in the two winters, so we could find no explanation of the higher counts in climatic conditions. During both winters the river was completely frozen over.

The chemical and physical characteristics of the water also vary widely. There are a number of paper and pulp mills on the river above Watertown, both chemical and mechanical processes being used. The effect of the chemical waste is quite apparent in times of low water in the river. A change of color of twenty-five parts per million (platinum scale) in four hours is not unknown here. This may mean an increase of 30 per cent. in the color in four hours. This color change is frequently accompanied by a decrease in the alkalinity of the raw water.

Since the installation of the filtration plant there has been a marked reduction in the typhoid death-rate, as shown by Table I in the paper under discussion, and a still more marked reduction in the typhoid morbidity rate, as is shown by the following table based on figures obtained from the annual reports of the local health officer:

TABLE VIII.

Year.	Population.	Cases of Typhoid.	Cases per 100 000.	
1900	21 696 (census)	193	877	
1901	22 400 (estimate)	150	670	
1902	23 200 "	306	1 319	
1903	23 900 "	231	967	
1904	25 000 "	703	2 812	(Epidemic year. Filter plant in operation September 12.)
1905	25 447 (census)	108	424	
1906	27 500 (estimate)	130	473	
1907	30 000	103	343	

In considering the morbidity rate it should be remembered that Watertown is the center of a large district having no hospitals except those in Watertown, so that a considerable proportion of the cases reported are imported, —brought to the local hospitals for treatment and reported from there. For instance, in 1907, the only year for which I have the figures, there were 20 such cases, or 19.4 per cent. of the total cases reported. If these 20 cases be deducted the morbidity rate becomes 277 instead of 343.

I know of no local explanation of the higher mortality and morbidity rates for 1906 than for the other years since the filtration plant was established. I understand that typhoid was more prevalent than usual throughout northern New York in 1906, so it seems to have been a general condition rather than a local condition.

Previous to the installation of the filtration plant high monthly typhoid morbidity rates were rather general, occurring at no particular season; but since the installation of the plant the high morbidity rates have occurred in the fall months, when other causes than water supply are most active, as shown in Table IX.

The filtration plant in Watertown has been in operation now about three and one-half years, and it may be of interest to consider

TABLE IX.

CASES OF TYPHOID BY MONTHS.

Month.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
January	13	23	180	7	7	18	2
February	16	47	302	4	10	7	3
March	37	29	101	17	4	8	
April	30	18	31	7	6	7	
May	26	3	19	3	2	6	
June	18	9	3	0	1	9	
July	22	23	11	3	3	0	
August	28	22	3	8	15	9	
September	39	21	21	12	26	15	
October	30	14	13	20	26	15	
November	20	7	14	10	18	3	
December	27	15	5	7	12	6	

the operation a little more in detail. The figures given in the following tables show this clearly. These figures are in all cases the monthly averages obtained from the records kept at the filtration plant. Table X shows the principal water quantities for the period.

During the winter of 1904–5 the water consumption was very high owing to leakage and waste, largely the latter. A campaign against this waste resulted in a lower consumption, but as the city grows larger the consumption is going up again, so that there have been times this last winter when it was difficult to keep up the supply of filtered water.

It will be noticed that during the last three months for which figures are given above, the period of service has been longer than usual; in fact, it has been necessary to make a rule that the filters should be washed at the end of forty-eight hours whether or not there was need of it to keep up the supply of filtered water. We ordinarily wash when the water falls to a certain level in the clear water well, experience having shown that, with us, this is better than washing at a certain loss of head on the filters.

The low values for the amount of water filtered between washings in the months of June, July, August, and September, 1907, were due to difficulties in the operation of the plant ensuing from the low stage of the river.

TABLE X.

Month.	Amounts of Water Filtered in Million Gallons per Day.	Percentage of Wash and Waste Water.	Number of Filters Washed Daily.	Period of Service in Hours.	Amount of Water Filtered between Washings, in Million Gallons.
1904.					
October....	4.418	6.7	12	15.40	0.371
November..	4.622	3.6	8	24.58	0.575
December..	5.250	3.8	11	18.59	0.475
Average .	4.760	4.7	10	19.52	0.473
1905.					
January ...	5.458	3.2	8	21.57	0.674
February ..	6.090	4.6	15	13.62	0.409
March	4.980	4.2	12	16.45	0.417
April	4.157	3.0	6	27.91	0.643
May.......	4.322	3.8	10	18.38	0.432
June.......	4.662	4.6	11	17.63	0.457
July.......	4.541	3.9	7	20.05	0.428
August	4.296	5.3	11	16.81	0.414
September .	4.283	3.4	7	25.04	0.568
October....	3.797	3.5	7	21.26	0.546
November .	3.909	3.7	7	25.96	0.548
December..	4.234	3.3	7	26.37	0.601
Average .	4.561	3.9	9	20.92	0.512
1906.					
January ...	4.302	3.3	7	26.95	0.617
February ..	4.326	3.2	7	26.17	0.617
March	4.274	3.1	7	24.49	0.602
April	3.850	2.8	5	29.79	0.749
May.......	3.282	3.2	7	24.43	0.653
June	4.177	4.3	9	22.56	0.595
July.......	4.184	4.5	10	20.04	0.501
August	4.096	4.5	10	20.91	0.495
September .	4.058	4.3	9	23.77	0.526
October....	3.793	3.8	7	24.59	0.563
November .	3.485	2.5	5	39.98	0.726
December..	4.108	2.9	6	29.46	0.773
Average .	3.995	3.5	7	29.10	0.618
1907.					
January ...	4.142	2.3	5	33.66	0.942
February ..	4.908	2.9	7	26.18	0.782
March.	5.219	3.5	10	19.19	0.605
April.	4.630	2.6	7	28.93	1.079
May.......	4.536	3.0	8	26.31	0.700
June.......	4.534	4.0	9	22.73	0.474
July.......	4.530	5.3	12	15.95	0.356
August	4.743	4.9	13	13.42	1.355
September .	4.493	5.4	13	13.49	0.342
October....	3.910	3.6	7	22.07	0.528
November .	3.482	2.7	5	32.36	0.763
December..	3.887	2.2	3	47.79	1.217
Average .	4.418	3.5	7.6	25.17	0.679
1908					
January ...	4.214	2.9	4	43.12	1.117
February ..	4.910	2.2	5	37.06	1.063
Average .	4.562	2.55	4.5	40.09	1.009

Table XI shows the amounts of coagulant used and effect of filtration on the water.

Our highest raw water colors occur in the summer and autumn when the river is lowest, and at these times the color is also subject to considerable variations, necessitating careful watching of the raw water and regulation of the amount of alum used. The maximum raw water color (day's average color) was 140, and the minimum, 38.

The turbidity of the raw water is, as a rule, low. One day has shown a turbidity of 200. The minimum was 1; the average since the plant has been in operation, 10.

The alkalinity of the raw water has varied widely from a maximum of 80 to a minimum of 14. In 1905 the average raw water alkalinity was 39; in 1907 it was 28. There are, at times, from 1 to 5 parts of "suspended alkalinity" in the water, the exact source of which we have not been able to learn. In the earlier years of the operation of the plant it was never necessary to add alkalinity to the water except for a week or so in the spring when the snow was going off, but in 1907 it was necessary to add alkalinity (soda-ash) during parts or all of seven months —March, April, and May in the spring, and September, October, November, and December in the fall and winter.

It will be noticed that the amount of coagulant was increased greatly in the winters of 1906–7 and 1907–8. This was due to the greatly increased number of bacteria in the raw water as shown in Table VII. Ordinarily sufficient alum to reduce the color to a satisfactory amount, below 10, is more than enough to guarantee the hygienic efficiency of the plant, so that we can regulate our alum feed according to the color of the raw water.

From the time the plant was put into operation until the first of March, 1908, there have been tested at the plant 14 474 samples of water, including about two hundred fifty samples analyzed in connection with investigations of the pollution of the river. Samples of raw and filtered water are taken every four hours throughout the twenty-four for chemical and physical tests. Bacterial analyses are made daily except Sunday. These show that the bacterial efficiency of the plant is good and that the removal of coli is general also.

TABLE XI.

Month.	Color.		Turbidity.		Alkalinity.		Coagulant Used.	
	Raw.	Filtered	Raw.	Filtered	Raw.	Filtered	Pounds per Million Gallons.	Grains per U. S. Gallon.
1904								
Oct.	103	15	18	0	28	14	376	2.63
Nov.	64	7	7	0	31	17	257	1.80
Dec.	51	8	4	0	35	19	242	1.69
Av.	72	10	9	0	31	17	291	2.04
1905.								
Jan.	53	8	5	0	40	24	238	1.67
Feb.	47	9	3	0	35	19	234	1.64
March	44	10	12	0	37	21	261	1.83
April	57	6	22	0	23	9	244	1.71
May	67	11	5	0	28	14	240	1.68
June	90	14	14	0	33	15	309	2.16
July	104	13	8	0	36	14	379	2.65
Aug.	82	16	9	0	42	19	358	2.51
Sept.	80	11	9	0	42	17	352	2.46
Oct.	80	9	9	0	47	20	351	2.46
Nov.	77	10	8	0	49	22	349	2.41
Dec.	52	9	8	0	56	34	242	1.69
Av.	69	11	9	0	39	19	296	2.07
1906.								
Jan.	51	7	23	0	54	37	257	1.80
Feb.	48	10	9	0	44	28	260	1.82
March	42	6	13	0	41	25	259	1.81
April	44	3	16	0	33	22	235	1.64
May	51	8	12	0	29	22	215	1.50
June	73	10	11	0	34	23	300	2.10
July	87	9	9	0	38	24	346	2.42
Aug.	79	11	5	0	42	22	364	2.55
Sept.	75	9	2	0	27	9	356	2.49
Oct.	74	13	7	0	34	17	322	2.25
Nov.	64	9	18	0	36	20	322	2.25
Dec.	60	7	9	0	35	19	323	2.26
Av.	62	9.5	11	0	37	22	297	2.11
1907.								
Jan.	56	4	22	0	29	11	325	2.26
Feb.	45	4	8	0	29	10	361	2.53
March	47	1	19	0	29	9	414	2.90
April	56	0	22	0	27	18	363	2.55
May	61	0	10	0	29	12	364	2.55
June	65	2	5	0	29	11	348	2.44
July	87	8	3	0	30	11	358	2.51
Aug.	84	14	6	0	33	13	354	2.48
Sept.	89	12	7	0	30	10	365	2.56
Nov.	87	7	12	0	24	11	363	2.56
Dec.	71	5	14	0	28	15	366	2.57
Av.	69	5	11	0	28	12	362	2.53
1908.								
Jan.	54	1	4	0	30	14	358	2.51
Feb.	56	4	9	0	29	13	376	2.64
Av.	55	2.5	6.5	0	29.5	13	367	2.57

Full records of the operation of the plant are kept. The filter attendants are required to keep an hourly record of the amount of coagulant used, the quantity of water entering the plant, the amounts of water in the coagulating basins and clear water well, the losses of head on the individual filters, and full details of all washings of the filters. These are all checked up daily by the superintendent of the plant, who also keeps records of all water quantities passing through the plant, the amounts used in washing and waste, the amount of water pumped into service, the amounts of water on hand at the end of the day in each of the various basins, the amounts of coagulant used and on hand, and full records of the bacteriological, chemical, and physical tests made on the water.

Besides the superintendent there are three filter attendants, each working an eight-hour day.

The plant also possesses an alum storehouse capable of holding six months' supply of alum if need be. This was deemed advisable as the rigor of northern winters sometimes interferes materially with freight traffic.

The cost of operation of the plant since it started has been as given below in Table XII.

TABLE XII.

Chemicals	$13 924.52
Salaries and supervision	12 607.55
Repairs, new sand, extra labor, grading, and new construction	1 889.05
Coal	1 102.83
Freight, cartage, and miscellaneous	1 035.45
	$30 559.40

This makes the cost of filtration per million gallons, without allowing for depreciation and interest on the capital invested $5.57.

Dr. E. S. Willard * (*by letter*). I have not had an opportunity to read this paper carefully, but from my knowledge of Dr. Soper and his work I have no doubt that the epidemic and the campaign against it have been accurately described. This is, in fact, the only account of the outbreak which has appeared, so far as I know.

It may be of interest to state that the general course followed by the city of Watertown in its crusade against the fever was in

* Health Officer, Watertown, N. Y.

accordance with a suggestion made by Dr. Soper himself several months before the epidemic broke out. When we first realized that an epidemic might be upon us and that extraordinary measures might be necessary to put a stop to it, I remembered a paper which I had heard read at the third annual conference of Health Officers of New York State, at Albany in October. The title of this paper was "The Management of Typhoid Fever Epidemics," * and it was delivered by Dr. Soper soon after he returned from the typhoid epidemic at Ithaca.

Many of the steps which should be taken to put a stop to an epidemic of typhoid were described in the paper. It was pointed out, however, that the details suited to every situation could not all be described and that the best thing for a local board of health to do in case of epidemic was to call on the state for an expert to come and direct the sanitary campaign. If the state could not supply such a person, an outside expert should be called upon. To quote from the address, Dr. Soper said:

"I am aware that in expressing an opinion favorable to what may be considered a state management of epidemcis I am recommending a course which appears to be different from that ordinarily followed in this commonwealth. But the difference is more seeming than real. It has been the custom on occasions of severe epidemic for the State Department of Health to send a representative to investigate the cause of the trouble and to recommend measures for the elimination of the cause. The visit of the expert has usually been brief, two or three days ordinarily being considered sufficient for his investigation.

"The suggestion that I make is that the state send a representative to remain long enough at the seat of epidemic to insure the adoption of measures which will bring it under control, whether this takes three days or three months."

When the epidemic began at Watertown, the State Department of Health was informed that typhoid was prevalent and a question was asked as to what, if anything, should be done about it. In response to this appeal the state sent Professor Landreth, who made an investigation into the cause of the epidemic and gave much good advice but whose other duties would not permit him to remain continuously at Watertown to fight the epidemic to a finish. There then remained the second alternative to consider,

* *Medical News*, New York, January 2, 1904.

namely, for the city to employ an independent expert. This was done by engaging Dr. Soper. He came within forty-eight hours and remained with us two months.

From first to last the relations between the state and local boards of health were cordial and, as far as the city was concerned, satisfactory. Dr. Soper acted in an advisory capacity, strengthening and supplementing the board with the results of his special training and experience and taking charge, as far as legal restrictions would permit, of a large amount of the executive work which was involved in carrying out his recommendations. The activities of the board were, of course, greatly increased in scope and number. No new laws or special ordinances were passed. The theory was that there would be enough sanitary regulations to meet the case if those already enacted were properly enforced. After the campaign was over the board returned to its usual and customary operations.

Mr. M. N. Baker * (*by letter*). It seems a great pity that Watertown, Ithaca, and Butler did not have the services of Dr. Soper before instead of after their typhoid fever outbreaks. It is certainly to be hoped that the time is not far distant when communities of this size and larger will each and all have in their employ scientifically trained men of experience and tact who will constantly guard them against both epidemic and endemic preventable diseases.

The slowness of both the city and state authorities to act at the time of the Watertown outbreak seems almost unaccountable. The State Health Department was not called upon until January 30, after some two hundred cases of typhoid had been reported within the month. The representative of the State Health Department did not arrive in Watertown until February 8, and even then he seems to have done little but give some general advice, after which he hurried away, to go back later for another brief visit.

The local authorities seem to have made no use whatever of the rules for the protection of the water supply formulated by the State Health Department. Why not? Their failure in this respect, and the apparent failure of other communities to make any very great use of like rules, suggests the utter inadequacy of this plan

* Editor *Engineering News*, New York, N. Y.

for protecting public water supplies in the state of New York. In the case of so large a drainage area and so small a community as were involved at Watertown, it is perhaps too much to expect that local authorities could effectively protect themselves against pollution under such rules as were authorized by the New York statute; particularly in view of the fact that the expenses for removing or preventing pollution are placed upon the community whose water supply is to be benefited thereby.

An explanation from some source seems to be demanded of the high typhoid death-rates that have prevailed in Watertown since the filtration plant was put in operation. In the light of our present knowledge of such matters it would appear that other sanitary reforms than an improvement in the public water supply are greatly needed at Watertown.

Water-works officials ought to realize, as few of them yet seem to do, the importance of doing all in their power to see that local boards of health do some effective work in tracing each case of typhoid fever to its source of infection. If this were done many a water supply which has been otherwise put in question would be exonerated, and, far more important still, many lives would be saved.

MR. KENNETH ALLEN * (*by letter*). A public calamity that affords so excellent an object lesson in the exposition of its cause and in the means taken to eradicate the evil and bring about far better conditions than previously existed may be looked upon, from one point of view at least, as a blessing in disguise. The reduction in the typhoid death-rate from an average in 1885 to 1903 of 71, and in 1904, 194 per 100 000, to 24, 50 and 37 per 100 000 the following years, is an index of the direct effect of the house-cleaning the city of Watertown went through, but the indirect effect with its saving of life in other communities is much greater.

In this connection the various means taken to disseminate knowledge concerning the epidemic and its control, by lectures and by inviting the coöperation of the Chamber of Commerce, the Department of Charities, etc., must have gone far toward stamping out the epidemic and in counteracting the unaccountable

* Division Engineer, Sewerage Commission, Baltimore, Md.

attitude of *laissez faire* which existed. It is difficult to so convince the average citizen of the necessity of boiling a suspicious drinking water that he will see to it that it is regularly done. And if, perchance, this point is gained, the chances are nine to ten that he will not insist on equally sterile water for washing dishes, brushing teeth, and drinking when traveling.

For this reason the supplying of pure spring water at a nominal cost during epidemics of this kind is a step of much importance, and should always be done when practicable. So, too, in the preparation and distribution of disinfectants, as " white liquid " and " blue liquid," with simple directions to facilitate their safe and effective use by ignorant persons, good judgment was shown.

The failure to profit by the warning of the epidemic of 1895, and the continued high typhoid rate, seem inexcusable, but in this Watertown has not shown herself different from the average community. In matters of this kind safety is only secured by the constant vigilance of some responsible authority having power to act. The most obvious person to be clothed with such authority is the health officer. But in cases of water supplies and stream pollution the offense is so often committed beyond the jurisdiction of the local authority that, as in this case, the state must be appealed to through its Board of Health, whose executive officer, as well as the local health officer, should have power to execute the laws and ordinances governing the offense without further resort to higher powers. Beyond this come in the questions connected with the pollution of interstate streams, as the Mississippi, Missouri, Ohio, Delaware, Susquehanna, concerning which disputes, if not amenable to arbitration, must be referred to some Federal authority. Such cases are becoming more and more frequent with increased densities of population, and it is quite possible they may be best handled in connection with the question of water transportation and water-power by a Federal commission independent of, but coöperating with, and coördinating the efforts of, the several departments of the government. Such a division of authority would be elastic, in harmony with the general theory of our government, and would at the same time avoid division of responsibility. Moreover, it is directly in line with the present development in many of our states.

In the Watertown case the ineffective legislation of 1896 is instructive. With laws no doubt in the main good, and with power to act, yet they were rendered inoperative by imposing an unknown but possibly very great cost on the commissioners to whom their execution was intrusted. That fatal provision blocked the way at once to any abatement of the offensive conditions, and it was only after these became alarming and the higher authority of the state stepped in that efficient results were secured.

Fortunately the city and state coöperated in harmony, the former paying the latter for sanitary work on the watershed above by special agreement. The more definitely the line of responsibility can be drawn, however, between state and local jurisdiction in such matters, the better, and it would seem as if this might be accomplished at least to a greater degree than exists at present.

Mr. Francis F. Longley * (*by letter*). Dr. Soper's interesting paper sets forth in admirable manner the facts regarding this virulent outbreak of the dread typhoid in Watertown. It is of especial interest to the writer because of his connection with the water department of that city in charge of the operation of the filters during the year following the epidemic herein described. The filters, which were in course of construction at that time, were finished and put in operation early in the following September. They are of the "mechanical" type, and were fully described in the columns of the *Engineering Record* of dates May 21 and 28, 1904.

In watching the typhoid fever situation in Watertown during the first year of operation of the new filtration plant, the writer was impressed with one unusual fact. That was, that the typhoid death-rate fell from an average of 83 per 100 000 to 24 per 100 000 in that first year, in marked contrast to the gradual fall in typhoid death-rates in many other cities after the complete or nearly complete removal of the source of infection in the water supply.

The question that naturally arises is, What was the cause of this clean-cut drop in the typhoid curve? Was it the purification of the water supply alone, or were there other large contributing causes? The advocates of pure water and of filtration would be glad enough to take the credit for it in its entirety, but may they

* Chief Chemist and Assistant Superintendent, Washington Filtration Plant, Washington, D. C.

do this? The epidemic described in this paper was severe enough to thoroughly frighten the people of Watertown, frighten them into far greater precautions against infection by typhoid from all sources than they would have used except under the influence of such a fearful calamity. And it is logical enough to believe that these precautions that individuals took of their own free will had a very appreciable effect in preventing many cases that would otherwise have been contracted. This is not a new idea, nor is it hard to find evidence tending to support it. For instance, take the typhoid record Dr. Soper has presented for Watertown, supplementing it with the rates for the three years that have passed since the epidemic year, as shown in Fig. 13.

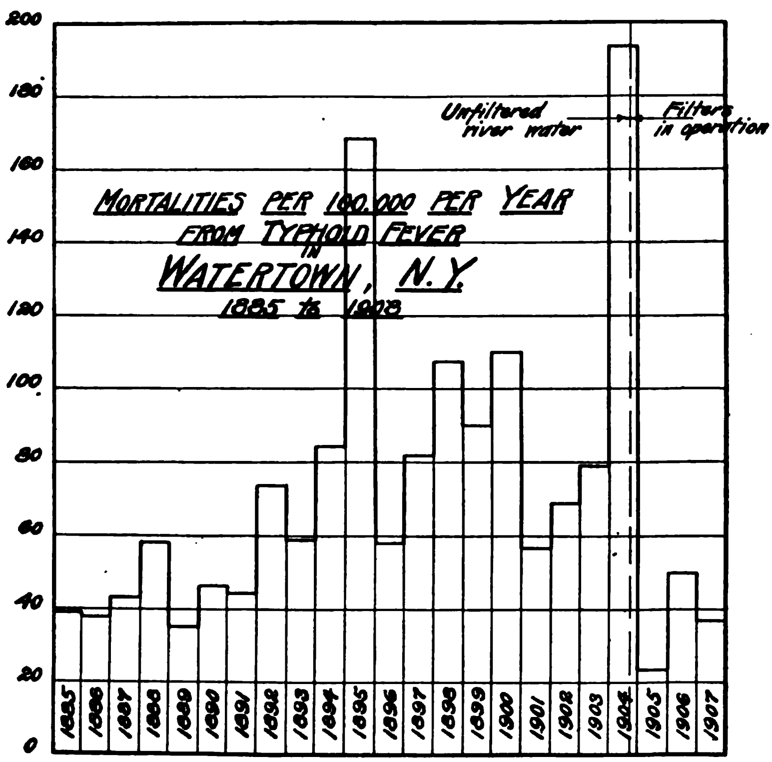


FIG. 13.

Dr. Soper speaks of the epidemics in 1895. They are very evident on this curve. Vigorous preventive measures were applied, largely through individuals. The result was that the curve for the following year dropped very low for Watertown. But it did not stay low. With the sense of security that came with the low rate of 1896, the individual seemed less impressed with the necessity for the vigorous precautions of the year before, and consequently we see the typhoid rate climbing up again.

No distinct epidemic has been noted for the years 1898–1900, but the conditions are plain, with an average typhoid death-rate for the three years in excess of 100 per 100 000. No doubt this caused a campaign, following the high rate of 1900, against the infection, with the result of bringing the rate down in 1901 to 57 per 100 000. Then again the curve rises for several years until it culminates in the epidemic which forms the subject of this paper.

In the year following the epidemic year the typhoid death-rate dropped, as is shown, to 24 per 100 000, which is lower than it had been in more than twenty years for which records are available, and considerably less than one half the low rates reached in 1896 and 1901. A mass of most conclusive evidence points to the improvement in the water supply as the large factor in this reduction of the death-rate; but is it not very probable that the preventive measures prosecuted so vigorously the year before had a decided influence in reducing that portion of the typhoid that was not affected by the improvement in the water supply? And is this not borne out by the fact that the rate jumped up again the two succeeding years, indicating as before the wearing off of the educational effects of the epidemic year in the security apparent in the minds of the public from the improved conditions and the lowered death-rates?

The curve of typhoid fever death-rates for Washington, D. C., has during the past twenty-five years shown variations of this same nature that were not explainable by any known changes in the quality of the water, and for which the ideas suggested above do seem to afford a reasonable explanation. The curves for many other cities, too, show similar variations.

There are many factors, such as meteorological, climatic, and racial conditions, as well as the questions of pure water and proper

drainage, that influence typhoid rates in ways that are too devious to follow, and there is no intention of arguing the elimination of such considerations nor of pretending to dismiss with one simple argument a question which is of the most serious complexity. This discussion is presented simply with the idea of bringing out the importance of two points: First, the educational effect upon a community of a distinctly epidemic typhoid condition, with all the object lessons attendant thereon; and second, the error that has been so commonly made in placing the entire blame for high typhoid rates upon the water supply, even when that is known to be badly polluted. It is evident enough that the degree to which the water supply alone may be blamed varies with the amount of pollution; but even assuming this to be a very considerable degree, the other causes tending to produce typhoid are generally not insignificant, and they should not be overlooked, as has so often been done.

A great deal has been said upon the subject of typhoid fever in Washington since the installation of the filtration plant nearly three years ago. This city had long been afflicted with a high typhoid rate, and the water supply, drawn from the Potomac, had been blamed for it. Naturally all agreed in predicting a great reduction in the typhoid with the use of the purer water supply. And naturally all were disappointed and mystified upon seeing the typhoid appear with no diminution in quantity or intensity during the first year of operation of the filters. This had the effect of bringing down much unfortunate and sensational criticism of the water supply, and the new filters were advertised far and wide as a failure.

The results of the studies on the quality of the water, both before and after filtration, the results of investigations that have been carried on for two years by the Public Health and Marine-Hospital Service, the close consideration of the problem by the health department of the District of Columbia, the deliberations of the Medical Society of the District, and the opinions quite unanimously formed by the many sanitarians and experts who have given this subject their consideration, all point to the conclusion that the early assumptions were wrong. The filters were not a failure, but were doing most excellent work. The advent of

filtered water did not cause a marked and prompt reduction in typhoid because the Potomac water was not a large factor in the causation of the disease. The importance of certain other factors, which had before been neglected in favor of the polluted water theory, was accepted and emphasized.

When, years ago, the relation was pointed out between polluted water supplies and typhoid fever, and emphasized by epidemic after epidemic of the most virulent nature, with the most convincing evidence to prove this relation, the dangers lurking in polluted water were preached far and wide; and in the light of the evidence adduced, the theory of water-borne typhoid was almost universally accepted.

This was right and proper. The facts in a great many spectacular outbreaks of typhoid fever have been so closely in accordance with this theory as to eliminate every doubt of its application to the cases in question. There is an element of danger, however, in the too complete acceptance of this theory. There is danger of forgetting almost entirely that the disease may have its origin in many other causes. In their highly commendable enthusiasm over the application of this theory, some of the ablest writers in the country on sanitary subjects have entirely ignored this possibility. And therefore it is that the writer wishes to comment in this way upon the too complete acceptance of the water-borne typhoid theory to the exclusion of other factors, the importance of which has been underestimated. Engineers know without question how to eliminate the typhoid that is carried through water supplies; and there the function of the engineer ceases, or rather merges in with that of the municipal official upon whom falls the burden of dealing with that part of the typhoid which has been called "residual." The indications seem to be that in some communities this "residual" typhoid may be a large part of the whole, and the need of greater knowledge in regard to it is evident. In connection with some problems it has been thoroughly studied with promising results in some directions, though less so in others, but it should be persisted in without discouragement.

The importance of education in this subject of typhoid has been mentioned. An epidemic is a good means to that end, but it is an expensive and heart-rending, as well as an impressive ex-

perience. Education through the medical fraternity seems logical for this subject, but it has been found unsatisfactory and ineffective. The same is true of bulletins, circulars, and newspaper publicity. But could any means be found more satisfactory than through the public schools? For the subjects of study of the school children, if of human interest, very quickly become the subjects of discussion and perhaps of further study in the home. They need not be techanical; the less technical, in fact, the better. There are a few admirable books that would answer the purpose, and the writing of others awaits only the creation of the proper demand.

The writer is inclined to offer an apology for dwelling upon topics that lie more strictly within the realm of education and of medicine, but while they are of little value to a superintendent in checking waste, or to an engineer in the selection of pumps, they are pertinent in the discussion of a subject which concerns us all, as this does.

One other point the writer wishes to refer to is a case of gross carelessness in the pumping station at Watertown. The regular intake extends, as Dr. Soper has stated, to a settling basin. During the construction of the filters and the extension of the intake to the new plant and coagulating basin the city supply was drawn partly through an emergency supply pipe directly from the flume along the east side of the building. About 50 or 60 feet above this emergency intake, and situated within the pump-house, was the toilet-room jutting out over the flume, a splendid opportunity for another spectacular outbreak of typhoid by a very direct transmission of infectious material, only wanting the proper individual, and disgusting from its evident proximity. Inquiry failed to reveal any one who had suffered from the fever, and who had worked in, or frequented the pump-house. The danger from this source was eliminated, of course, when the proper intake to the new filters was put in service, and later the toilet-room itself was removed. But it is an example of the dangers that may lurk right under the official eye and escape detection in the general search that is made for sources of pollution.

Dr. Leonard P. Kinnicutt * (*by letter*). No one can read Dr. Soper's most interesting and instructive paper on the 1904 typhoid

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

epidemic at Watertown, N. Y., without feeling how great are the strides made by epidemiology during the past two years, and how differently a typhoid fever epidemic is handled to-day than it would have been yesterday.

Yesterday we sought for the primary cause and, finding it, we contented ourselves with an attempt to prevent further spread of the disease from the original source, leaving almost untouched all secondary causes. To-day it is considered that unless all possible means are used to prevent the indirect spread of the disease, comparatively little has been done.

Koch's investigations at Triers showed that for the prevention of the spread of typhoid fever almost as great precaution must be taken as is the case with scarlet fever or diphtheria; and possibly the most interesting part of Dr. Soper's paper is the description of what might almost be called the extreme measures that were used at Watertown to prevent all possible sources of danger of the infection being carried from person to person; and to those familiar with city governments it shows what "courage of conviction" is able to accomplish; and there is no question that the work of Dr. Soper will be of great use and make the work of the epidemiologist in the future much easier in persuading city officials that only by the most thorough measures can an epidemic of typhoid fever be stamped out.

Possibly one point in Dr. Soper's paper that is not sufficiently dwelt upon is regarding the closing of all suspicious wells. This, of course, may have been done at Watertown, though the statement that the result of the examinations of the wells showed that the water of most of them was of an unsatisfactory quality, yet only in a few cases were the wells ordered closed, leaves the question somewhat in doubt. In times of epidemics it would certainly be best to close all wells which gave any indication of pollution.

Dr. Soper, in speaking of the mechanical filtration plant which was in course of construction at the time of the epidemic, gives the typhoid fever rate since it was put in operation, in 1905, 24 per 100 000; in 1906, 50; and in 1907, 37; but makes no comment on these figures. Professor Sedgwick, in referring to them and to the continued typhoid at Washington since the slow sand filters were put in commission, states that in his belief it is due to residual

typhoid or to typhoid due to other causes than the public water supply. Not questioning at all the fact that typhoid is due to other causes than polluted water, is it not possible that the prejudice of the French sanitarians against filtered water and the present tend in Germany to the development of ground waters as a source of supply is not without justification?

DR. M. J. ROSENAU * (*by letter*). In addition to the many excellent features of Mr. Soper's report, one is especially impressed with the fact that Watertown got off very cheaply. The efficient and energetic measures adopted to suppress the epidemic were put into effect at a small cost, compared with the price of life and health. Watertown owes to the sanitarian a debt of gratitude. Ordinarily it takes a catastrophe to stimulate a community to adopt vigorous sanitary measures. It is a matter of much regret that cities suffering with residual typhoid, or with typhoid in what might be called the *status epidemicus* cannot be stimulated to adopt vigorous suppressive measures.

DR. SOPER. Among the many interesting questions raised in the discussion of this paper, there is one upon which there is substantial agreement. All agree that typhoid must be regarded as not merely an infectious disease, but as one that is contagious as well. The fact that a public water supply must not be alone held responsible for cases of sickness in an epidemic like that at Watertown is recognized by all. The general acceptance of this view is peculiarly agreeable to me since, as Professor Sedgwick says, my convictions with respect to this point have strongly influenced my work for the last five years. That the plan for the Watertown campaign has met with approval at the hands of the very experts whose opinions I most value is very gratifying.

There never was any doubt in my mind as to the effectiveness of the work. To stop the epidemic a sum approximating $25 000 was spent in two months. The epidemic had been running without abatement for two months. Within two weeks after the measures of suppression were put in force, the number of new cases each day diminished to about one half, and although the epidemic continued for nearly two months longer, its intensity never again increased, but diminished steadily to the end. If the table given in the body

* Public Health and Marine-Hospital Service, Washington, D. C.

of the paper showing the number of cases reported daily does not indicate the effectiveness of the suppressive measures, I am at a loss to comprehend to what cause the diminution is to be attributed.

The only regret is, as Mr. Baker has pointed out, that the work of stamping out this epidemic was not begun earlier; that it was not, in fact, made unnecessary by preventive and remedial sanitary measures applied to the water supply years before. Health Officer Willard in his discussion has explained why some valuable time was lost. Acting on advice which I myself had given in a paper read before the assembled health officers of New York state some months previously, the city of Watertown applied to the New York State Department of Health before seeking help from outside sources. Had the state responded to the call with the promptness and thoroughness which the situation demanded there is no reason why the city should not have had relief three weeks earlier. The delay in calling upon the State Department and the indifference with which the citizens had continued to drink polluted water from the Black River for so many years prior to the epidemic can only be attributed to apathy, an apathy which, as has been pointed out by Mr. Whipple, is not peculiar to Watertown. Apathy toward typhoid exists everywhere in the United States.

The personal element enters into the cause of typhoid fever to a far greater extent than is commonly understood, for typhoid is transmitted from one person to another not only in epidemics, but at all times. The cause of this personal transmission is due, in the last analysis, to individual ignorance and indifference.

The time has passed when a single channel of transmission like a public water supply should be held accountable for all the cases of typhoid which occur in an outbreak. The possibilities of transmission from persons who are sick and from healthy bacillus producers are sufficient to account for many cases in every epidemic. I believe that practically all sporadic or prosodemic typhoid is produced in this way. Only by preventing typhoid from spreading in this way can we hope to eliminate it utterly. As Professor Sedgwick says, typhoid is commonly looked upon as infectious and not contagious. It is too often regarded as transmissible in only one way in an epidemic, as by water, for example. This is a mistake.

A point to which Professor Kinnicutt has alluded, and which

was apparently not made sufficiently clear in my paper, is the danger which is to be apprehended from local foci other than strictly personal ones. Wells belong to this class. There is no doubt in my mind that in typhoid epidemics, wells which are ordinarily only polluted sometimes become infected with typhoid germs and give rise to cases of typhoid which are attributed to the main source of infection. I found in the epidemic at Ithaca a well of this kind. The well had long been regarded as pure, and when the public learned that the city water supply was dangerous, as many people as possible turned with confidence to the well for their drinking water. So great was this confidence, and so large the demand on the well, that the water was piped from the private property upon which the well was located to another house in the vicinity. At first no trouble resulted. But toward the end of the epidemic a case of typhoid occurred in the house where the well was located. The attending physician did not recognize the sickness as typhoid, and the dejections were allowed to pass without disinfection through the sewer. The sewer was defective and the bacilli entered the well, producing fifty cases of typhoid with five deaths.*

The danger from wells was constantly guarded against at Watertown. Wells located on private property and in mills were examined with much care by means of analyses and inspections. One of the objects of the laboratory was to examine the waters of the wells. At Ithaca 946 private wells had been examined under my direction, and at Watertown, although there were fewer wells, the work was no less thorough. The people were warned against the use of wells whose purity rested merely on common repute. It was generally necessary to present convincing evidence of danger in order to prove that the well was polluted, for people in small cities are as loyal to their wells and privies as though they were members of the family. But once the danger was made plain, a family would willingly abandon its well. Few wells were formally ordered closed for this reason. The object of the spring water supply distributed by the Board of Health was to cut off the need of using the public water and the private wells as far as practicable.

* "The Epidemic of Typhoid Fever at Ithaca, N. Y.," by George A. Soper, Ph.D., JOURNAL of NEW ENGLAND WATER WORKS ASSOCIATION, Vol. XVIII, No. 4, pp. 445–446.

I feared contamination of the milk supplies, for it is not uncommon in an epidemic like that at Watertown for country people who are attacked during temporary residence in the city to go back home to be nursed through typhoid. One case of typhoid in a dairy might very possibly cause many others. Here was a danger which it is extremely difficult for a city like Watertown, when afflicted by epidemic, to guard against. The farms which supply the milk are likely to be miserably dirty. To at once raise them from their filthy state to such a condition of sanitary excellence as to exclude the danger that the milk may become infested with typhoid germs is impossible. I am confident that in some of the long and intense typhoid epidemics which have afflicted American cities, milk supplies have become foci of typhoid germs long after the original cause of the epidemic has ceased to act. At Watertown the Board of Health sought to combat this danger by warning the public against drinking raw milk and by exercising such supervision as was practicable over the sources of the milk. It is proper to say that these precautions were not as thorough as was desirable, but no milk supply was found to be contaminated.

Along with such foci as water and milk belong dangers incident to the consumption of fruit and other food which are handled and exposed for sale within an infected city. At Watertown an Italian fruit dealer who was found to be harboring a case of typhoid in his establishment was given the choice of closing his shop or having the patient removed to hospital.

Mr. Whipple has said that the original source of the infectious matter seemed to be less effectively guarded against than the local sources. This criticism is, in a measure, just. The public water supply was, in my judgment, so heavily polluted that no measures intended to exclude or remove the polluting matters would be at all likely to prove successful. It seemed to be a sheer waste of time and money to attempt to " clean up " the drainage area, as is so often attempted in epidemics. Two months of spring weather probably had done much more than human effort could do to remove all the defilement which it was practicable to remove.

On this point there was, as pointed out in the paper, a clear division of opinion between the state department of health on the one hand and the city department of health on the other. It

was not doubted by either that the typhoid epidemic had been brought upon the city by the water and that permanent sources of pollution still existed upon the river. But it seemed to me impracticable to do away with these sources. Because of the great expense involved it had been impossible for the water board to avoid them by enforcing the state law. The drainage area was extensive and at several places villages and mills crowded the river banks, and even islands in the river were built upon. Several sewerage systems were discharging into the stream when the epidemic broke out. These sewerage systems could not be eliminated. So far as typhoid was concerned, it was necessary first to find the infectious matter before it could be removed. The investigators available for this undertaking were such young men as happened to be out of employment and could be induced to take up this work. They knew nothing of sanitation. The inhabitants of the drainage area were by no means all on friendly terms with the city and it seemed undesirable to earn their hostility by a clumsy interference with what they had long considered were their rights. The details of the procedures which should be followed in the event of a case of typhoid being discovered were by no means well defined. Obviously they should vary with circumstances. The best that could be done would be to trust to the judgment of the inspectors. In view of the fact that the city had its hands full in guarding against local sources of infection, it seemed far better to leave the cleaning of the drainage area to the state department of health, place emphasis upon the fact that the river water was dangerous and must remain so, and at the same time place within the reach of all an abundant source of water of unquestioned purity.

At the same time, by special arrangement with the authorities at Deferiets, a number of cases of typhoid in that village were taken off the sewerage system and provision was made for disinfecting and disposing of the excreta in a sanitary manner. The hospital facilities at Watertown were extended, as always, to the country people. The laboratory facilities of the Watertown Board of Health were placed at the disposal of all physicians on the drainage area for the discovery of typhoid cases and of people who were not sick but who were unconsciously producing typhoid

bacilli. In this way a little boy was discovered who had recovered from typhoid and who was being sent to school in one of the villages on the river above Watertown with urine literally clouded with typhoid bacilli.

With so many possible sources of typhoid within and near the city, it is not strange that the epidemic, once started, should have been of long duration. In fact, it is not clear why typhoid should ever be completely stamped out without careful, skillful, and long-continued effort. In some epidemics it seems not to stop until every susceptible person is attacked.

The danger of an indefinite continuance of typhoid seems the greater when we consider the part played by healthy bacillus carriers in the dissemination of the disease. In the case of a chronic bacillus carrier whom I happened to discover in 1906, seven separate household epidemics were produced over a period of five years, a record which probably would be increasing to-day were it not that the unfortunate person who was producing the germs was taken into custody by the New York City Department of Health and detained as a menace to the public health.* In numerous occurrences of typhoid in Germany, and in a notable outbreak just reported by Dr. R. M. Buchanan, of Glasgow, the danger of unsuspected typhoid bacillus carriers in dairies, and wherever food is handled, has abundantly been set forth.

The bearing of all these facts upon typhoid is evident. Residual typhoid no longer necessarily means, as we all understood the term to mean when Professors Sedgwick and Winslow originally proposed it, the typhoid which remains in a city after the public water supply has been perfected. It may mean the typhoid which remains when the sources which lie within the city have been satisfactorily eradicated and only the water supply remains open to suspicion. In many instances these proximate sources may alone be to blame. The experience of Washington, and the thoughtful remarks of Mr. Longley in connection with this subject, well illustrate the necessity of taking advanced ground in accounting for the presence of typhoid fever everywhere.

As Professor Kinnicutt has said, great progress has recently

* "The Work of a Chronic Typhoid Germ Distributer," by George A. Soper, Ph.D., *Journal of the American Medical Association*, June 15, 1907.

been made in our understanding of the cause of typhoid, and the opinions of yesterday are no longer those of to-day. But there still remain some obscure problems connected with this subject. I agree with Professor Winslow in believing that we are only at the beginning of our knowledge of typhoid, and I cannot share Mr. Whipple's view that the ways in which the typhoid germ is transmitted and the ways of preventing this transmission are all well understood. I hope the knowledge of to-morrow will be considerably in advance of the knowledge of to-day.

Mr. Allen has raised an interesting question. He has called attention to the fact that typhoid epidemics are sometimes highly educational, and he and Mr. Longley have remarked that the sanitary instruction, coupled with the alarm which people experience at such times, apparently cause them to exercise precautions that, for a few years at least, after the epidemic, protect them to a considerable extent against typhoid. With this view I am in general agreement. But I cannot think that greater precautions alone account for the fact that in the year or two following an epidemic there is likely to be much less typhoid than previously existed. I think other forces are at work also.

Why Watertown has had so much typhoid since its epidemic of 1904, I am unable to explain. Mr. Jennings suggests that it is because the country people in the vicinity use the city hospitals, and Mr. Whipple gives a number of reasons for thinking that the filter plant is not to blame. On the other hand, Professor Kinnicutt plainly intimates that he is not perfectly assured of the infallibility of filters. Mr. Longley apparently thinks the disease is being spread through lax sanitary precautions. This point is an extremely interesting and important one, but I confess I know nothing whatever about the persistence of typhoid in Watertown since the epidemic. I agree in thinking this question should be cleared up.

An obscure point in the epidemiology of typhoid is the fact that strangers are more likely to be attacked on visiting a typhoid city than are the customary residents. At Ithaca typhoid was prevalent for years among new students at Cornell University. So disproportionately large was the number of freshmen attacked that the disease which filled the infirmary every fall was called

"freshman fever." Troops sent to a distance are said to be much more liable to typhoid soon after reaching their destination than subsequently. Similarly, typhoid epidemics appear to be most intense in places where the people have previously suffered least from that disease. It is possible that the epidemic at Watertown would have claimed more victims at the outset had the water supply not been so contaminated and typhoid so common in other years. Does continued exposure to the germs always either produce typhoid fever or confer immunity? There is here a most interesting field for research.

It is difficult to account for the obscure question of the seasonal distribution of typhoid to which Professor Winslow refers. Excluding epidemics due to surface water supplies, typhoid is, in northern countries, chiefly a disease of autumn. I believe that people are more exposed to typhoid germs at this season than at any other. At this time people are moving about the country more freely than at other seasons, exposing themselves and others to an unusual extent. Probably people are more susceptible to typhoid in the autumn. This may be because of changes in diet, or it may be because of certain unusual metabolic conditions due to changes in temperature. Certainly personal susceptibility changes from day to day and it probably varies from season to season.

Is it not possible that the difference in seasonal incidence of typhoid among Indian and British troops mentioned by Professor Winslow may be due to some difference in personal habits? I cannot think that the temperature of the summer or early autumn has any material effect upon the vitality or virulence of the typhoid organism outside of the body, or that the weather directly affects one class of men in one way and another in an opposite way. I am inclined to believe that the causes which lead to the prevalence of typhoid in the autumn are due to (1) greater personal susceptibility; (2) greater exposure to the germs.

Before attempting to explain what appears to be the excessive prevalence of typhoid in some American states as compared with others, I should like better assurance of the correctness of the statistics. It is a cause of just reproach that vital statistics are so inaccurate in America. Even the statistics of deaths are unreliable in our most enlightened states, and this being so, what

reliance can we place upon the reports for the whole country? In the masterly investigations made into the causes of typhoid fever among the American troops in the Spanish War, Drs. Reed, Vaughan, and Shakespeare considered that not over 50 per cent. of the typhoid cases were discovered by the average civilian physician. This is not denying, however, that typhoid is more prevalent in warm countries than in northern ones. There is much evidence to support the interesting point raised by Professor Winslow.

Mr. Allen and Mr. Longley, Mr. Whipple and Mr. Baker, have urged the necessity of official action in respect to the control of typhoid fever, and the suggestions which these gentlemen make are worthy of most careful consideration. There is need of defining city and state limits of supervision over the pollution of streams; there is need of really useful state rules for the protection of surface water supplies; water boards should insist that boards of health trace typhoid cases to their sources. Physicians should report their cases of typhoid. It is high time that the principles of sanitary science applicable to the prevention of typhoid were recognized by educational authorities and taught more rationally and effectively in the schools.

As Professor Sedgwick has eloquently and forcibly pointed out, the keynote to better work in the prevention of typhoid lies in adopting higher standards of living. Higher standards should be established in every branch and department of public health work, including the conduct of public water supplies. The adoption of higher standards can alone eliminate typhoid.

Typhoid will continue to be prevalent so long as indifference toward it continues. The tribute which the American people are paying for this indifference is the loss of not less than 20 000 lives, $150 000 000, and the heart-rending miseries which are entailed by over 300 000 cases of typhoid annually.

THE TROY WATER WORKS EXTENSION.

BY E. L. GRIMES, CITY ENGINEER, TROY, N. Y.

[*Read March 11, 1908.*]

HISTORICAL.

The city of Troy is located on the easterly bank of the Hudson River, at the head of navigation. It occupies the river plain for a distance of about six miles north and south and extends back upon the hills to the eastward from one to two miles. The river plain has a general elevation of about 30 feet, while the hills occupied on the east rise to elevations of from 300 to 500 feet above tide-water. At the time the water works system was first undertaken, the city had a population of about 12 000; it now has a population of about 77 000.

The Troy Water Works Company, a private concern, was incorporated by act of the Legislature, April 18, 1829. This company intended to supply water for domestic purposes only and seems to have accomplished very little.

About a year after the company above referred to was incorporated, the Common Council of the city passed a resolution creating a committee with instructions to make surveys, plans, and estimates for bringing " a suitable supply of good water " into the city. On August 11, 1830, this committee reported upon two plans, — one to take water from the " Gorton Springs," at an estimated cost of $60 000; the other to use the " Piscawen Waters," at an estimated cost of $80 000.

In May of the following year a committee was appointed to see what arrangements could be made with the Troy Water Works Company to supply the city with water for extinguishing fires, watering streets, etc., and to learn upon what conditions the company would transfer its charter rights to the city, provided the necessary legislation could be obtained. The committee reported, March 26, 1832, that they could not make satisfactory arrangements with the Troy Water Works Company for the supply required,

but that the company had agreed to surrender its charter to the city upon the payment of the amount actually paid out by them, $174.34. The committee further reported that the legislature had already passed the necessary bill for the transfer, by an act entitled," An Act in Relation to the Troy Water Works Company and for insuring the City of Troy a Supply of Water for the Extinguishment of Fires and for Other Purposes."

Acting upon this report, the Common Council ordered a house-to-house canvass to be made to ascertain the sentiment of the people in regard to the matter. As a result of this canvass, it was found that 637 were in favor, 8 opposed, and 18 indifferent to the project. One hundred and seventy-eight agreed to take water when it was brought into the city.

Surveys for the construction of the reservoirs upon the Piscawankill were begun in March, 1833, and contracts for the work were immediately made. A contract was also made with Samuel Richards, of Philadelphia, to furnish cast-iron pipe and castings at the following rates delivered in Troy: 12-inch, $1.85 per foot; 10-inch, $1.50; 8-inch, $1.30; 6-inch, $0.90; 4-inch, $0.50; 3-inch, $0.40 per linear foot, and branches and other castings, $62.50 per ton.

The works were completed in 1834 and consisted of a diverting dam across the Piscawankill; two open and one covered reservoirs, having a combined capacity of about 1 000 000 gallons, and a 12-inch main leading from the covered reservoir to the city. The ruins of these old reservoirs are still to be seen just easterly of the Boston & Maine Railroad near Eddy's Lane.

The work had been completed but two years when it became evident that some means should be devised to increase the supply. In 1839 land was purchased and a dam known as the Fire Dam was built for the purpose of storage upon the site now occupied by the low-service distributing reservoir. This reservoir appears to have been insufficient, for the next year the committee in charge suggested pumping water from the Hudson River.

The idea of pumping seems to have been abandoned for some reason, and in the fall of 1840 the right was obtained to erect and maintain a dam at the site now occupied by the dam of the Brunswick reservoir for the term of two years, with the privilege of

buying the property outright at the end of that period if the city elected to maintain a permanent reservoir at that point. The dam was built and all the property rights were later acquired.

The full development of the Piscawankill watershed as a water supply was finally accomplished by building the present "Upper Oakwood" reservoir in 1859–1860, the "Lower Oakwood" in 1861–1862, and the "Vanderheyden" reservoir in 1868. These reservoirs, together with the "Brunswick," gave a total available storage capacity of about 281 000 000 gallons.

In 1872, Wm. J. McAlpine, civil engineer, who was employed to examine all the feasible sources of water supply for the city of Troy, and report on the cost of procuring the same, made a report in which he suggested five sources of supply, namely, the Tomhannock, the Poestenkill, the Hudson River, the Deepkill, and the Wynantskill. In concluding his report, he says: "The Tomhannock plan possesses advantages over all of the others in the economy of its cost and the purity of its water, and is equal to any of the others in the abundance of water." None of the schemes suggested by Mr. McAlpine was carried out.

In 1877 and 1878, Prof. D. M. Greene, civil engineer, presented reports and plans for pumping water from the Hudson River, and in 1879 a pumping plant was built under his direction. This plant consisted of two Holly duplex pumps, each of 6 000 000 gallons daily capacity, together with the necessary intake crib in the river, a tunnel to convey the water from the intake to the suction well, and a 30-inch cast-iron force main extending from the pumping plant to the "Lower Oakwood" reservoir, a distance of about three miles.

The water was pumped from the river into the "Lower Oakwood" and allowed to flow by gravity from there to the distributing reservoir.

The low-service distributing reservoir was built in its present form in 1883, at which time a 24-inch supply main was laid from it to connect with the distributing system of the city. This line of main pipe crossed the stone arch just below the reservoir and connected with the 20-inch main of the old system near the old covered reservoir. Provision was also made at the new distributing reservoir for another 24-inch main. This was laid down

Eddy's Lane, or Glen Avenue, and Seventh Avenue to Park Street, connecting with the distributing system, in 1885.

The middle service system was connected with the "Upper Oakwood" Reservoir in 1879, and the high-service system was taken from a small new reservoir, known as the High Service Distributing Reservoir, built especially for that purpose during the same year.

The supply thus provided proved to be adequate until about 1893, when Prof. W. G. Raymond and Elnathan Sweet were employed to investigate and report upon a new source of supply. These engineers made a report upon the development of the Poestenkill and Quackenkill, two streams lying to the southeast of the city. Nothing further seems to have been done toward procuring an additional supply until 1900. In the meantime Professor Raymond's attention was directed to the Tomhannock Creek, a stream of considerable size flowing through the towns of Pittstown and Schaghticoke into the Hoosick River. He found upon investigation that a very large storage reservoir could be made there at comparatively small expense.

The Tomhannock Reservoir would not, however, be at a sufficient elevation to supply more than the low, middle and Lansingburgh services. Therefore it was finally decided to develop the Tomhannock for these services, and the Quackenkill for the high-service supply.

Authority to expend $1 250 000 for an additional water supply was obtained from the legislature in 1900, and the work was immediately undertaken under the direction of Prof. W. G. Raymond as consulting engineer.

THE QUACKENKILL.

The Quackenkill drainage area is located on the mountains east of Troy in the town of Grafton. It consists largely of grazing and wooded lands and contains several lakes of considerable size. These lakes are located in the more elevated portions of the area, are fed largely by springs, and contain water of very good quality. Streams flowing from the lakes join to form the Quackenkill. On account of its great elevation above the city it affords an excellent source from which to obtain, by gravity, an additional supply for

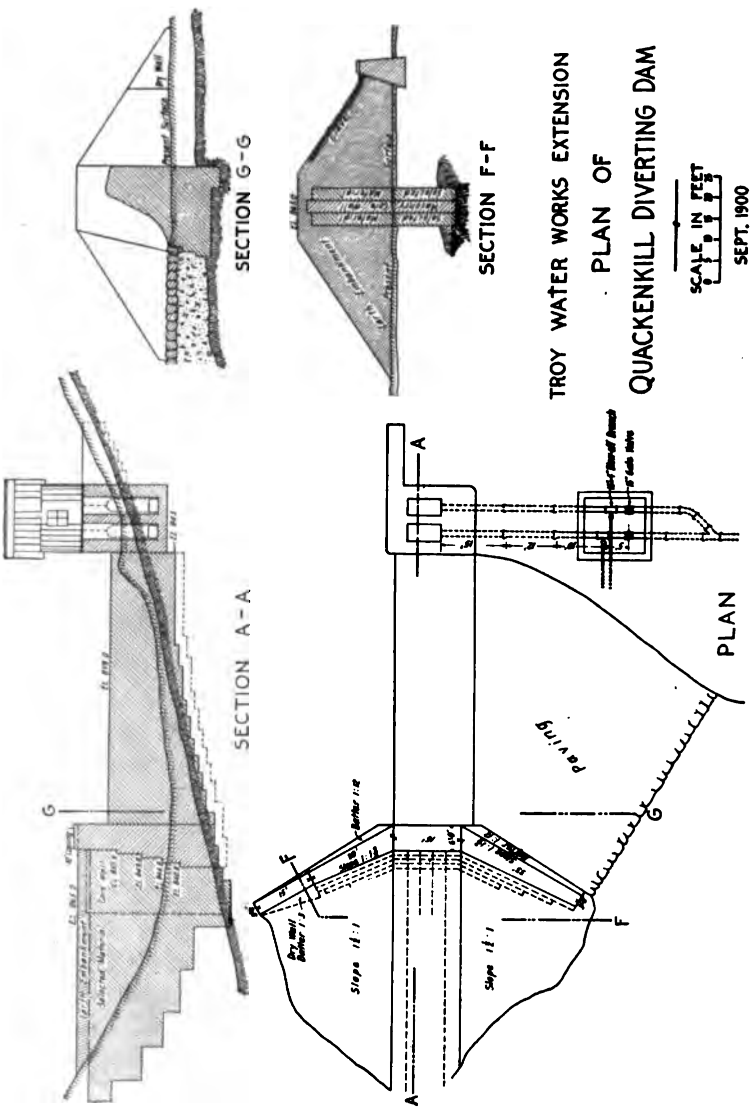

SECTION G-G
SECTION F-F
TROY WATER WORKS EXTENSION
PLAN OF
QUACKENKILL DIVERTING DAM
SCALE IN FEET
SEPT. 1900
SECTION A-A
PLAN
paving
Slope 1½:1
Slope 1½:1

FIG. 1.

FIG. 1. Quackenkill Diverting Dam and Gate House.

FIG. 2. Tomhannock Dam Site with Culvert Completed.

the high-service system of the city. The original plans contemplated the full development of about 17½ square miles of the drainage area around the headwaters of the Quackenkill.

To accomplish this it was proposed to build dams at the outlets of the lakes so as to increase their storage capacity; two large storage reservoirs, one about 2 miles and the other about 5 miles below the lakes; a diverting dam near the town line between Grafton and Brunswick; one or more conduits from the diverting dam to the large storage reservoir, known as the "Brunswick," about 3 miles distant from the city; and a conduit from the "Vanderheyden Reservoir," to connect with the old high-service conduit at the old high-service distributing reservoir. Up to the present time the only work carried out under these plans consists of the building of the diverting dam, a single conduit from it to the storage reservoir, and a single conduit from the storage reservoir to connect with the old high-service main.

The diverting dam (Fig. 1, and Plate I, Fig. 1) consists of a concrete spillway and gate chamber, and an earth embankment with concrete core-wall. Although only one conduit has been laid from the dam to the storage reservoir, the proper connections, valves, etc., have been built into the dam for a second one, if it should ever be needed.

The conduit from the diverting dam to the "Brunswick Reservoir" consists of 29 550 feet of 16-inch, and 3 167 feet of 12-inch cast-iron pipe designed to have a carrying capacity of about 5 000 000 gallons per 24 hours. The outlet of this conduit is taken some distance into the reservoir, where it terminates in a bell-shaped concrete mouthpiece. This mouthpiece turns upward and serves to a small degree as an aërating fountain.

From the "Brunswick" the water passes over a weir or through pipes in the embankment into the "Vanderheyden Reservoir." A new intake gate-house has been constructed at the dam of this reservoir. It was built with hollow brick walls filled in solid with concrete. Vitrified paving brick were used below the high-water line, and ordinary hard burned building brick above that line. A 20-inch conduit was laid from this gate-house to a connection with the old high service conduit. This conduit is 9 000 feet in length and gives an additional static head of about 90 feet.

It also eliminates the possibilities of contamination, which so largely existed in the open channel, through which the water formerly flowed.

THE TOMHANNOCK.

The Tomhannock drainage area is located northeasterly of the city and comprises above the reservoir dam an area of 67.3 square miles. The surface is very uneven, being of a rolling or mountainous character. It is largely a farming district, only about 15 per cent. of the area being covered with forest growths. There are about 600 houses on the drainage area and a resident population of about 2 500, or 35 people per square mile.

The location selected for the reservoir is about 10 miles northeasterly of the city. Here the valley of the Tomhannock, for a distance of 5 miles, has an average fall of about 8 feet per mile and an average width of about three quarters of a mile. At the point selected for the dam, the hills on either side of the valley approach each other until only a narrow ravine lies between them.

The hills surrounding this valley are of a shale formation with only a thin covering of earth. The valley is covered with glacial drift a few feet in depth, with here and there a deposit of considerable magnitude. Bed rock is found below this glacial deposit in the upper part of the valley of the same general character as in the hills around it.

At the dam site and for a distance of three quarters of a mile upstream, where the bed rock drops off abruptly, the material underneath the glacial deposit consists of a thin layer of yellow clay overlying an extremely hard and compact blue clay and gravel, extending to a depth of more than 150 feet, as shown by borings.

The crest of the spillway dam is located at Elevation 390, Troy City datum, at which elevation the reservoir has an area of 1 685 acres. The maximum depth of water near the dam is 55 feet, and the average depth over the whole area, 22.4 feet. The total capacity of the reservoir is 12 310 000 000 gallons, 95 per cent. of which is available for use.

Of the area flooded, 250 acres were covered with woods and brush, the remainder being largely lands under cultivation. The trees and brush were all cut and removed from the area. The

farm buildings, of which there were seventeen sets, were entirely removed and the areas occupied by them carefully cleaned up; 22 000 cubic yards of muck and decaying vegetable matter were excavated and removed from the area flooded.

The question of stripping the soil from the entire area covered by the reservoir was carefully considered by the writer. The conclusion was finally reached that while stripping would be a very good thing, better and more far-reaching results could be obtained for about one half the cost by a reasonable sanitary treatment of the drainage area, and by installing a proper filtration plant.

Several highways crossed the reservoir site, and it was therefore necessary to construct about seven miles of new highways to replace those abandoned. The alignment of these roads has been made to conform in a large measure to the contour of the ground. The maximum grade allowed was 5 per cent. The subgrade was shaped so as to have a crown of 6 inches, over which was spread a gravel surfacing 9 inches in thickness at the crown and 6 inches at the shoulders, thus giving the finished surface a crown of 9 inches. The finished width of traveled way is 20 feet. The gravel surfacing was thoroughly rolled with a grooved roller and wet when found necessary to thoroughly compact it. Side gutters 2 feet in width at the bottom and 1 foot in depth extend through all excavations. A ditch was also constructed along the side hill above all excavations, with a berm of not less than 6 feet between it and the top of the slope. All embankments exposed to the wash of the reservoir are covered with riprap or stone paving. Substantial guard rails have been erected along all embankments 3 feet or more in height.

The culverts consist of 6-, 10-, 15-, and 24-inch vitrified clay pipe with concrete or cobblestone headwalls. These culverts have not been entirely satisfactory, especially in clay soil or where a small trickling stream flows all the time.

There are five bridges on the highways, with spans varying from 16 to 80 feet. The 16-foot span bridge was built with rolled I-beams. Three others were built with lattice girders, and floor systems of rolled I-beams. The fifth, an old bridge, was raised 4 feet and new abutments built under it. All abutments were built of 1 to 6 gravel concrete.

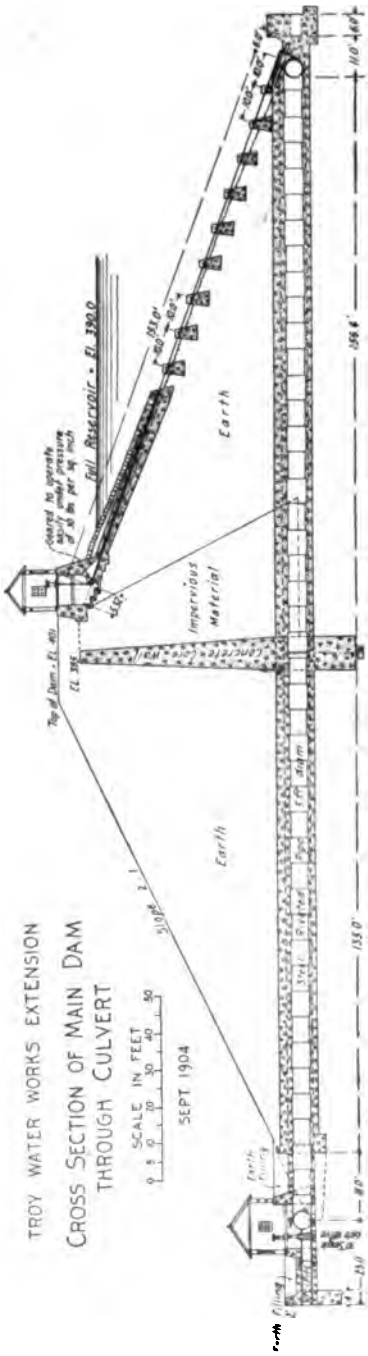


FIG. 2.

At the point selected for the dam the ravine is about 200 feet in width at the bottom and 500 feet at the top of the dam. An examination of this site had revealed the fact that it would be impracticable to reach bed-rock. Test pits dug along the proposed center line of the dam showed a depth of from 1 to 5 feet of loam and gravel, followed by a blue clay and gravel of unusual hardness and tenacity. This latter material is of great depth, as shown by the borings, and the formation was considered exceptionally good for an earth dam.

The general cross-section of the dam finally adopted, as shown in Fig. 2, has a top width of 24 feet, finished off as a highway; a back slope of 2.4 to 1; a front slope of 2 to 1; and a maximum height of about 70 feet. The back slope is paved to a point 15 feet below flow line and the remainder is covered with riprap.

The dam site was stripped of all loam and gravel down to the yellow clay. The area to be covered by the selected hard material was excavated down to and about 6 inches into the hard blue clay and gravel. There was also a cut-

off trench 4 feet in width and 2 feet in depth excavated along the toe of the up-stream slope, and another about midway between the toe and the selected hard material. The trench for the core wall was excavated to a depth of not less than 16 feet into the hard blue clay and gravel. At the westerly end, as the excavation was extended into the hill, a pocket of loose blue clay and gravel of a very porous nature was encountered, and it was found necessary to excavate to a depth of about 60 feet to procure a suitable foundation.

To provide for the flow of the stream during construction, a culvert 6 × 6½ feet, horseshoe-shaped, was built of concrete along the westerly side of the stream and the water turned into it by means of a canal and small cofferdam. It was the intention of the designer of the work to eventually close this culvert with concrete and gravel. With this in view two 36-inch sluice gates were placed at the upper end to control the flow through the culvert. These gates were of sufficient size to take the ordinary summer flow of the stream. Before the completion of the work, however, it was considered advisable to have a permanent opening through the dam at this culvert in order to unwater the reservoir should circumstances require it; a wise precaution in this particular case, as will appear later. This culvert is shown in Plate I, Fig. 2.

The plan followed for converting this culvert into a permanent opening was to build into and through it a 5-foot diameter steel riveted pipe ½ inch in thickness. At the upper end of this pipe is a T carrying three sluice gates, each having a clear opening of 1½ x 4½ feet. These gates were made narrow and long, so as to build them into and disturb the old work at the upper end of the culvert as little as possible. The gate stems were carried up the slope on bronze rollers, supported by concrete piers, to a gate-house located at the top of the dam. At the outlet end of the pipe is placed another T, carrying four 30-inch gate valves. This arrangement furnishes a means of regulating the flow through the pipe in case of accident to the sluice gates at the upper end, and of relieving the pressure upon them should it be necessary. A substantial brick gate-house is built over these gate valves.

The core wall of the dam is of concrete consisting of one part

Portland cement to five parts sand and gravel. The wall is 9 feet in thickness at the base and up to Elevation 340, from which point it batters uniformly on both sides to the top, at Elevation 395, where it is 3 feet in thickness. The concrete was deposited in 6-inch layers and thoroughly rammed. Above the surface of the ground the forms for the concrete were tied together with half inch rods. On the up-stream side a wooden washer in the shape of a truncated pyramid of four sides, about 2½ inches in height, was placed over the rod on the inside of the form. When the forms were removed the washers were taken out, the rods cut off at the bottom of the depression, and the space filled up with rich cement mortar.

The embankments on both sides of the core wall were carried up simultaneously with the wall, but the core wall was always kept at least one foot higher than the embankments, and usually much more than that. The embankments were always kept higher at the outside edges than at the center. The material for the embankments was brought from borrow pits in dump wagons and placed one load after another the whole length of the dam. After a line of loads had been completed, a road machine was used to scrape them down to a 4-inch layer. The layer was then watered and rolled thoroughly with a grooved roller weighing 1 000 pounds per linear foot. The teams were also kept from driving in one place as much as possible and thus aided in compacting the earth. The material from the borrow pits was not uniform in character, being at one place yellow clay and sand and at another almost wholly very fine sand or coarse gravel. As the loads came to the dam they were inspected and only the best material placed on the up-stream side.

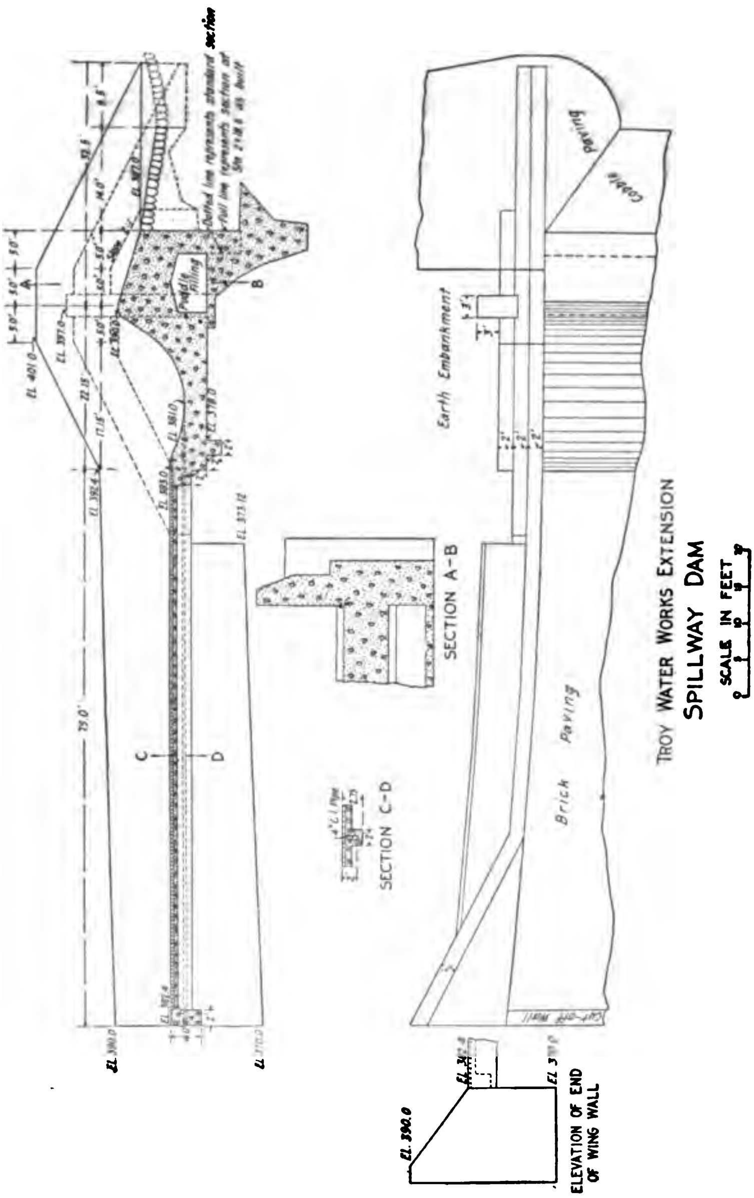
The selected hard material for that part of the embankment next to the core wall, on the up-stream side, was to have been of the hard blue clay and gravel underlying the valley. As it was found impractical to reduce it to a sufficient degree of fineness to puddle satisfactorily, a fine blue clay was substituted. This material was deposited and compacted in much the same way as the other material, except that greater care was taken with it. After the road machine had leveled off the loads and a disk harrow had been run over the material until all lumps were broken up, it

was thoroughly soaked with water and rolled. Near the core wall the lumps were broken up with mattocks and the material thoroughly compacted with hand rammers.

The embankments were carried 6 feet higher than the core wall and 11 feet higher than the crest of the spillway dam. Along the top of the embankment, on the up-stream side, a concrete curb was built, upon which was erected an iron pipe guard rail, while along the down-stream side the iron guard rail was placed on concrete blocks.

The spillway dam is located in a depression in the hills about 1 000 feet southwesterly from the main dam. It is built of concrete of the general cross-section shown in Fig. 3. The maximum depth of the cut-off wall is 25 feet below the crest. Back of this dam an 18-inch cobble paving is laid for a distance of 14 feet, with a slope of 2 feet in that distance. Beyond the paving the earth is excavated on a descending grade of 1 per cent. until it intersects the original surface.

The crest of this dam is 300 feet in length, and at each end are retaining walls rising to a height of 10 feet above the crest, to protect the earth embankment necessary to complete the dam. For a distance of 75 feet from the dam there was originally laid a vitrified brick pavement on 6 inches of gravel concrete, with a cut-off wall at the lower end. The retaining walls at each end of the dam are extended along and terminate in a twist wall at the end of the paving. From the spillway dam a canal is built around the hill at the westerly end of the main dam and enters the creek about one-half mile below. At the dam it was 300 feet in width, but narrowed down to 40 feet in going the first 800 feet. The canal was made in part by excavation and in part by building embankments. The embankments are 12 feet in width at the top and thoroughly rolled and compacted. At a point about 1 000 feet from the spillway dam the canal makes a descent of about 20 feet. To overcome the abrading action of the water at this point, two flights of stone masonry steps with retaining walls of concrete on either side were built. The upper flight consists of 7 steps of 1 foot rise each, and of width varying from 1 to 3 feet. The lower flight consists of 13 steps of 1-foot rise each and of width varying from 1 to 4 feet. Between the two flights of steps, a distance of



TROY WATER WORKS EXTENSION
SPILLWAY DAM
SCALE IN FEET
JAN. 6, 1908

FIG. 3.

FIG. 1. Spillway Dam.

FIG. 2. Condition of Apron of Spillway Dam after the Flood of June 23, 1906.

134 feet, and for 50 feet above the upper and 50 feet below the lower steps, the bottom of the canal is paved with vitrified paving brick laid on 6 inches of gravel concrete. A view of this dam is shown in Plate II, Fig. 1.

On the afternoon of Saturday, June 23, 1906, a shower of unusual magnitude occurred on the drainage area, being especially severe in the southerly part along the Grafton Mountains. At this time the water in the reservoir had just reached the elevation of the crest of the spillway dam. The water in the reservoir had not begun to rise at 6 o'clock Saturday evening, but at 9 o'clock the next morning it had risen to a height of 14 inches above the crest of the spillway. As soon as the high stage of the water was learned, the gates of the "Permanent Opening" through the main dam were opened and the water drawn down, thus relieving the spillway of a large quantity of water, and undoubtedly preventing a great amount of damage. Measurements showed the flow into the reservoir between 6 o'clock at night and 9 o'clock the next morning to be at the rate of 2 200 cubic feet per second, equivalent to 32.7 cubic feet per second per square mile, while the maximum flow over the spillway was about 1 300 cubic feet per second. The effect of this rush of water through the spillway canal was very disastrous under the existing conditions. Before the water could be entirely diverted from the spillway, the cut-off wall and a considerable portion of the brick paving below the dam had been undermined and destroyed, the canal had been badly eroded, and the highway bridge abutments undermined, as shown in Plate II, Fig. 2.

The canal is being reconstructed and widened. The plans now being carried out contemplate the widening of the narrow part of the canal to twice its former width, and the introduction of more steps and rollways so as to eliminate the steep grades in the canal that previously existed.

The city supply is taken from the reservoir through a tunnel 5 900 feet in length, the entrance to which is located about 1¼ miles southwesterly from the main dam. The gate-house at the entrance to this tunnel contains two chambers, each having three 36-inch sluice gates arranged at different elevations, so that water can be drawn at 8 feet, 21.5 feet, and 35 feet from the surface.

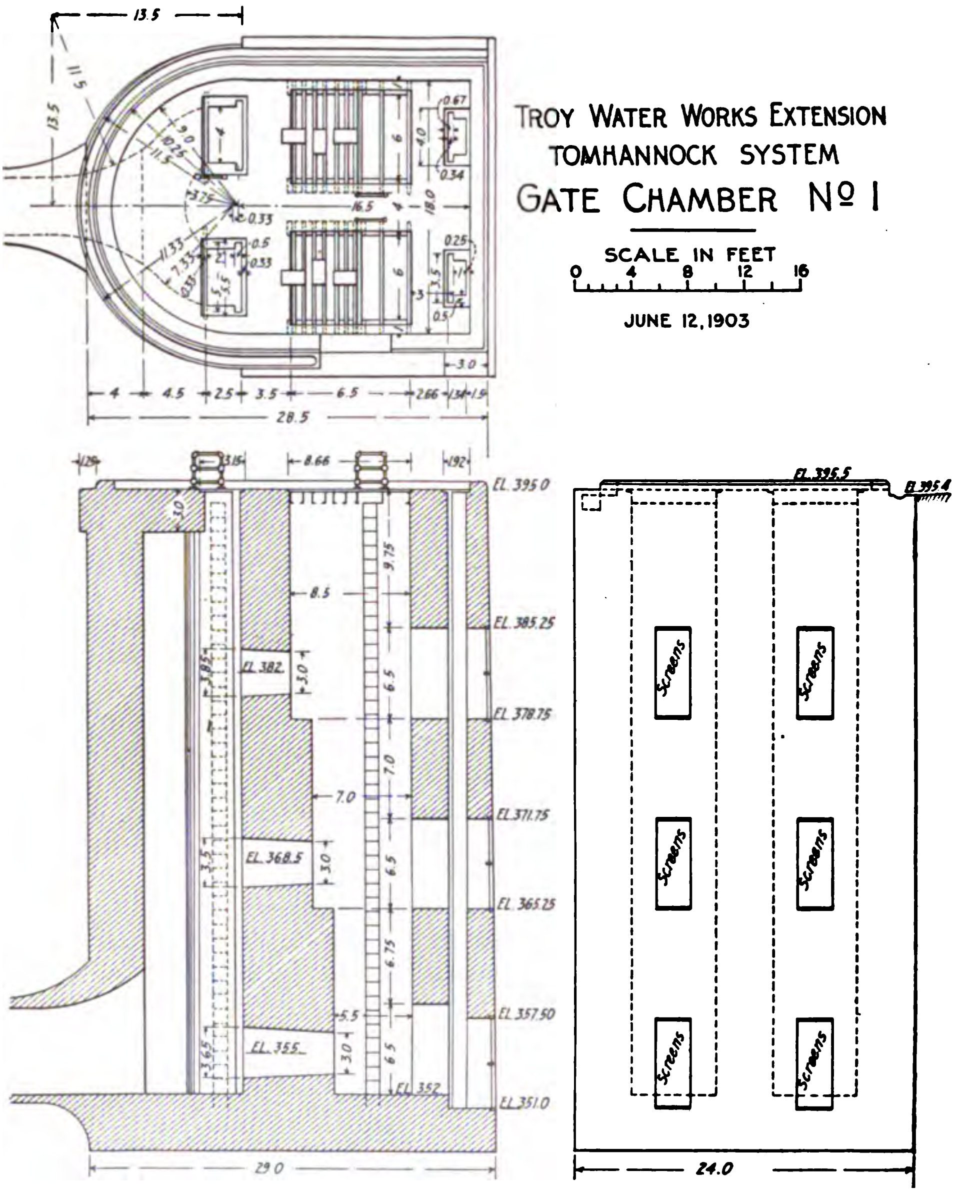

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
GATE CHAMBER No. 1
SCALE IN FEET
0 4 8 12 16
JUNE 12, 1903
Screens

FIG. 4.

Provision is made for stop planks on each side of the gates to assist in making repairs. The openings into the gate chamber are guarded by heavy bronze screens. (See Fig. 4, and Plate III, Fig. 1.)

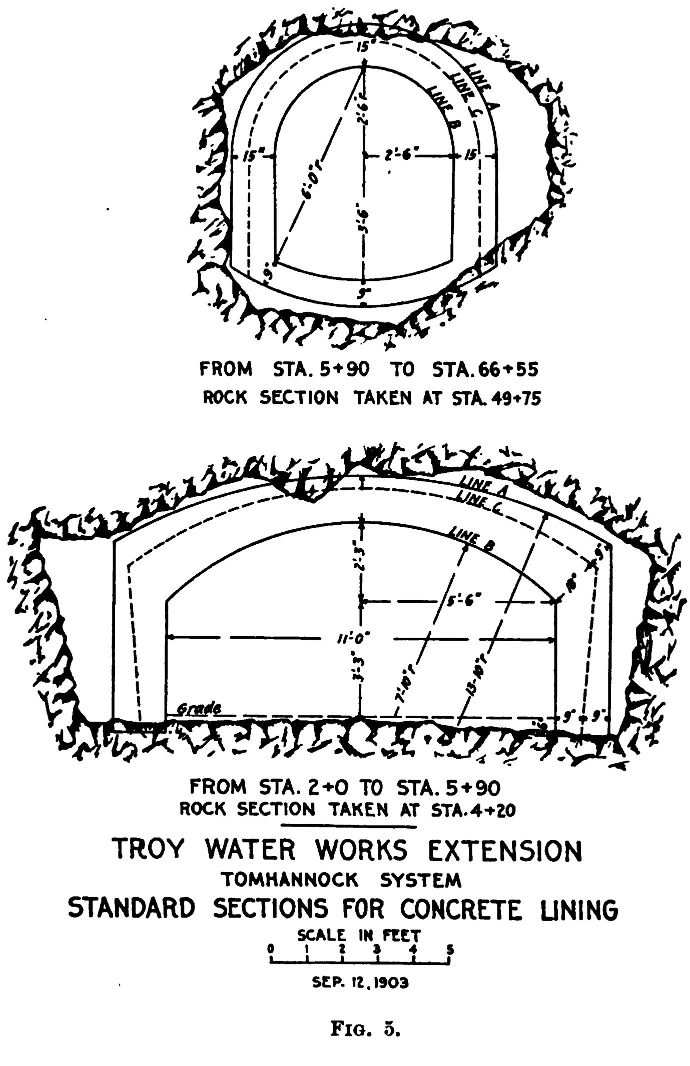


FIG. 5.

The first 5 470 feet of the tunnel was originally intended to have a cross-section of about 4 × 6 feet, and be unlined, while the remaining 430 feet was to be about 6 × 11 feet to allow of laying two conduits through it. It was afterward decided to line the tunnel with concrete. The cross-section adopted for the small tunnel has a semi-circular arched roof and is 5 × 6 feet inside measurements, and for the large tunnel 5.5 × 11 feet inside measurements, with segmental roof. (Fig. 5.) At the junction of the large and small sections of the tunnel a gate chamber is built, containing the gates which control the flow into the conduits. Access is had to the large tunnel through a well 5 feet in diameter, built at the opposite end from the gate chamber. All the structures connected with the tunnel below the surface of the ground are of concrete of the same proportions and material as used in the dam. The gate-houses above the ground are built of brick.

The tunnel extends its entire length through what is known as Hudson River shale. Near each end it appears laminated and has occasional soft seams, but as the tunnel penetrates further into it the rock becomes harder and the laminations are not so distinct. The dip of this rock is very irregular.

Excavation was carried on through four shafts and the opening at the end toward the reservoir. Steam was used for drilling during the sinking of the shafts and the driving of a few feet of the tunnel each way from them, but the greater part of the work was done with compressed air.

Only one conduit has been laid, although provision has been made in the tunnel for the second when it shall be needed. It consists of about 6¾ miles of 33-inch riveted steel pipe, connnecting with the old 30-inch cast-iron force main at Twenty-first Street, in the former village of Lansingburgh. From this point to the lower Oakwood Reservoir the old force main was utilized. The conduit has a carrying capacity of from 15 000 000 to 18 000 000 gallons daily. Automatic air valves have been placed at all summits, and blow-offs at all low points. Manholes are provided every 500 or 600 feet in the steel conduit. It is also provided with seven gate valves placed at approximately equal intervals along the line. At five points these gate valves are placed at summits in the conduit line and, together with the air valves, are

enclosed in small brick gate-houses. At the other two points the gates are in the street and the gate chambers are entirely underground. Access is had to these gate chambers through manholes built on the side. (Fig. 6.)

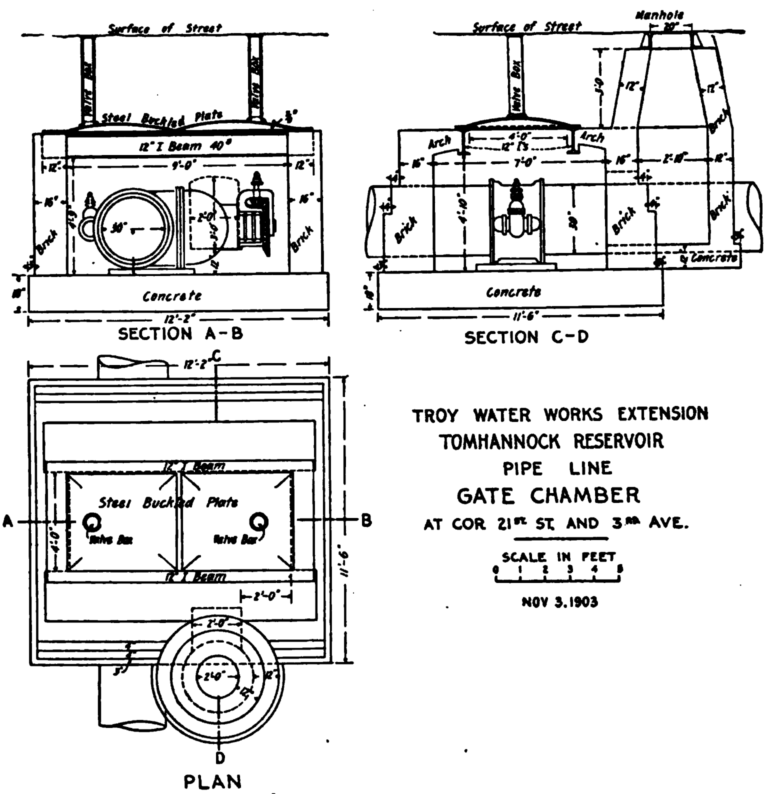


FIG. 6.

THE LANSINGBURGH SYSTEM.

The former village of Lansingburgh was annexed to the city of Troy in 1900. At that time Lansingburgh was supplied from three small reservoirs located just easterly of the village. It had also in the process of construction a masonry dam on the Deepkill and a 12-inch pipe line leading from it to the reservoir, to provide an additional supply. When the city of Troy came into possession of the work, Professor Raymond found that part of the new Deepkill dam rested upon rock foundation and part upon piles. After a careful examination of the location and conditions, he decided it would not be advisable to build the dam to its intended height, and consequently the upper 20 feet originally designed were never built.

The dam consists of a concrete core faced upon both front and back with coursed masonry. (Plate III, Fig. 2.)

What appeared to be a leakage under the dam was discovered near the center shortly after the work was completed. An attempt was made to check it by depositing clay and other materials above the dam, but this seemed to have little effect. While the quantity of water escaping was not large, a recent examination indicated some increase in volume, and that it was concentrated at a point a few feet to the right of the mud pipe near the center of the dam. The reservoir is of small capacity and only serves as a diverting reservoir.

The water-shed tributary to this system includes about 10 square miles of very hilly country lying adjacent to and westerly of the Tomhannock watershed.

QUALITY OF WATER.

The general quality of the water from all these sources is very good. During the month of January of this year, 1908, the Tomhannock water gave considerable trouble from algæ. The Quackenkill and Deepkill waters have been in use since 1902, and the Tomhannock since May of 1906. Prior to those dates most of the supply was pumped from the Hudson River into the low service reservoirs. The beneficial effect upon the health of the city of the introduction of the new supply is shown by the following table:

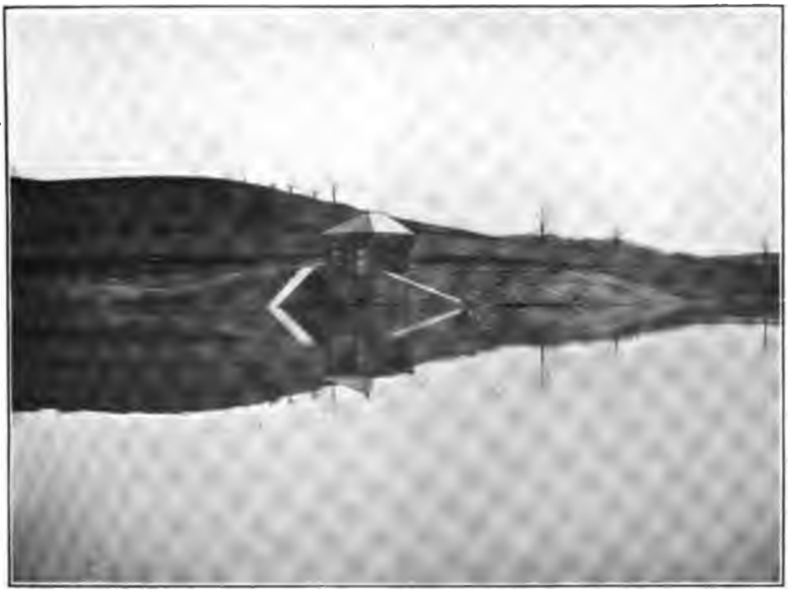


FIG. 1. Gate House at Entrance to Tunnel.

FIG. 2. Deepkill Dam and Reservoir, looking westerly.

Typhoid.				Deaths.			
Year.	Cases Reported.	Deaths.	Rate per 100 000.	Cholera Infantum.	Diarrhoea.	Diseases of Digestive Organs.	Children under 5 Years of Age.
1900	373	92	119.62	91	46	211	398
1901	176	43	55.91	56	45	178	370
1902	149	41	53.31	48	21	142	324
1903	110	23	29.91	19	10	97	315
1904	150	39	50.71	92	13	200	369
1905	160	39	50.17	70	14	184	394
1906*	91	27	35.11	24	12	113	317
1907	66	20	26.00	14	10	120	347

* Tomhannock water turned on May 21, 1906. Stopped pumping river water about May 1, 1906. Fifty cases and 15 deaths from typhoid fever reported before May 1, 1906. Average death-rate, 1901–1905, from typhoid fever, was 48.11 per 100 000. For 1906–1907 it was 30.56, or a reduction of 36½%.

COST.

The cost of construction of the different parts of the entire water works system to January 1, 1908, is as follows:

Original works and extension of Mains	$1 372 513.21
Original Lansingburgh Works	250 855.66
Deepkill System Lansingburgh Supply	150 507.67
Preliminary Investigations, Troy New Supply	25 545.18
Quackenkill System	265 916.75
Tomhannock System	1 337 138.12
Preliminary work on Filtration Plant	10 124.70
Total	$3 412 601.29

The plans for these new extensions were made under the direction of Prof. W. G. Raymond and the work was partially carried out by him. He severed his connection with the work in August, 1903, at which time the writer, who was the principal assistant engineer on the Tomhannock division, was appointed chief engineer.

POWER CAPACITY OF A RUNNING STREAM WITHOUT STORAGE.*

BY PROF. WM. G. RAYMOND, IOWA STATE UNIVERSITY, IOWA CITY, IA.

When a stream is to be developed for power, it is usual to examine such records of its flow as exist, and to take a few measurements of the minimum flow, if this is possible, as a basis on which to compute the probable minimum capacity and the probable ordinary capacity of the stream. The development is usually considered at some one point on the stream where a definite known head is available. When there are no records of the flow of the stream it is usual to examine its drainage area, compare it with that of some other stream for which there are flow records, compare also the rainfall on the two drainage areas, modify the percentage of rainfall running off from the area for which there are records, and determine the probable flow of the stream under consideration from its rainfall and these modified percentages.

While rainfall records are usually kept for each day, the published records are more commonly those of the calendar months, and this is true also of the flow records. In determining the percentages of flow on a given stream, it has been usually customary to average the flow for a number of years for each calendar month, and to compare this with the rainfall for the same calendar month for the same period. Among the streams of the eastern United States, it is found that as a general average about half of the rainfall runs off in the stream, the percentage varying in different years, according to the condition of the ground and according to the distribution of the rainfall. It is usual to say that the average conditions for power development will be shown by the average run-off or flow of the several calendar months of the year. And it is customary to determine what is called the ordinary flow,

* This paper, originally prepared for the Iowa Engineering Society, is now submitted as a discussion to the paper on "Stream Flow Data from a Water Power Standpoint," by Charles E. Chandler, published in the December, 1907, JOURNAL.

which is variously defined by different engineers, but which is understood usually to mean that flow for which it is wise to develop the stream for power.

If the calendar months are arranged in the order of their average yield, and the yields of these months are plotted to scale, a more or less irregular curve is the result, usually showing periods of regularity of from three to five months, broken by considerable differences of flow between these more regular periods. If, now, it is proposed to develop a stream for which such a plot has been made, and it is desired to determine for a given power development what portion of the year there will be sufficient water for the operation of the complete plant, and what portion of the year there will be shortage of water, and also the aggregate shortage for the year which must be made up by steam if a plant is to run continuously, the quantity of water necessary to supply the required power with the given head is determined and marked on the diagram. All those months which fall below the line of required yield will be short of power, while those months above will furnish full power, unless there be loss of head during extreme high water. Such a diagram, or such process, purports to show the conditions that will obtain as an average for the period of years that has been considered. The minimum flow at any one time indicates the maximum amount of power to be supplied by steam, and so, on such an investigation, a plant would be designed with a full water-wheel capacity and an auxiliary steam plant equal to supplying the maximum shortage of power. In estimating the cost of operating such a plant through a period of years, the average that has been mentioned would be considered.

It is a fairly well known fact that most plants that have been developed on such an investigation as this have proved disappointing in that the amount of water power available throughout the year has almost invariably fallen short of what was promised or expected, and consequently the auxiliary steam plant has been run at greater capacity and for longer periods than was estimated in the beginning. Indeed, some plants have been designed and built with the expectation that no auxiliary steam power would be required, while the first year's operation has developed the fact that considerable additional power would be needed.

The reason for this disappointment is not difficult to determine. If the records of flow are carefully examined, it will be found that there is no year of any considerable period of years in which there is not one or more months yielding considerably less water than the lowest average calendar month; thus, if by averaging the calendar months for a period of years, it is shown that July yields the smallest amount of water, it will be found to be true that in each year there will be one or more months, not always July,— sometimes January, sometimes September, sometimes May, sometimes some other month,—which will yield less than the average for July.

If there is no storage on the stream to equalize its flow, the more rational way of arranging the monthly records for power development is to average the lowest of the months of all the years, the next lowest, and so on; that is, the months of each year should be arranged in their order of flow, and the average of all the lowest months, next lowest, etc., taken. Such an arrangement of the months has been suggested by Professor Mead in his "Notes on Hydrology," which has just appeared. This is the first suggestion of this method of arrangement that the writer has seen, and this was not known until the notes for this paper were prepared.

The average of the months in their order of flow will show for the months of low flow a much less yield than the average by calendar months, and as the total flow must be the same, the averages of the high months are materially greater than the average of the high calendar months.

A diagram showing the two methods of averaging for the Sudbury drainage area covering a period of twenty-three years is shown in Fig. 1. The full line represents the calendar averages in order of volume discharged, the dotted line the averages of the months arranged in order of flow.

A similar diagram for the Perkiomen Creek, one of the streams that has been considered as a possible source of water supply for the city of Philadelphia, is shown in Fig. 2, the records extending over fifteen years.

Some time since, in the writer's practice, it became necessary to determine what portion of time a plant requiring about 170 cubic feet per second for its full power development would be without

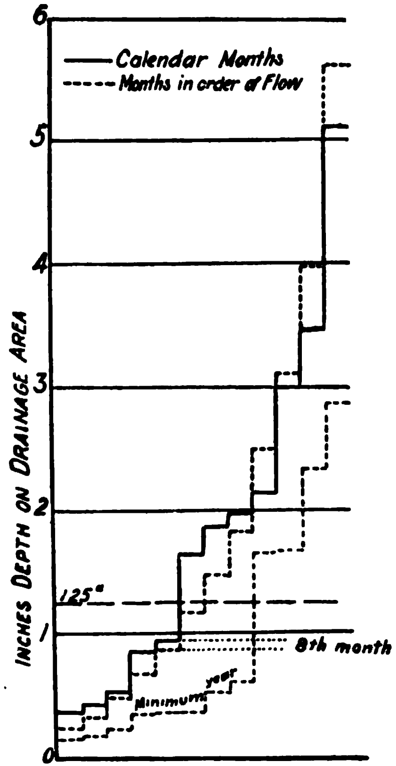


Fig. 1. Average monthly flow from the Sudbury Drainage Area for 23 years, in inches of depth on the area.

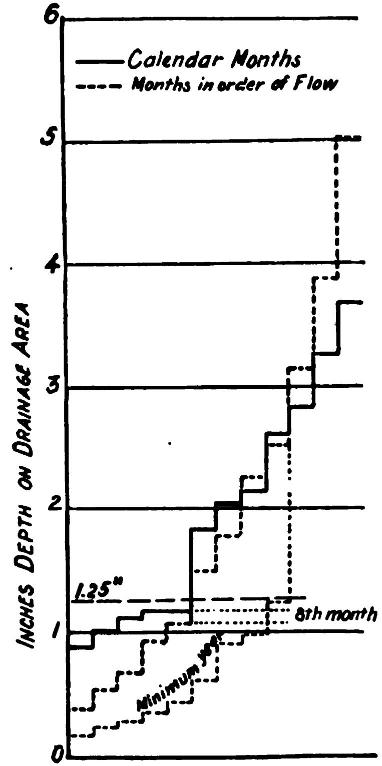


Fig. 2. Average monthly flow from the Perkiomen Drainage Area for 15 years, in inches of depth on the area

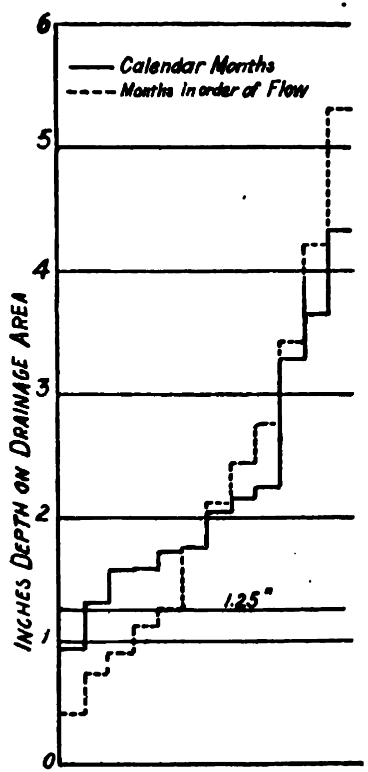


Fig. 3. Average monthly flow from the Perkiomen Drainage Area for 1887 '88, '89, '90, '91, and 93 in inches of depth on the area

full power. This plant was located on a stream not unlike the Perkiomen and of approximately the same drainage area. One hundred and seventy cubic feet per second is equivalent to 1¼ inches on the drainage area of the Perkiomen. Drawing the horizontal line on the diagram representing 1¼ inches, it is seen at once that by the average of calendar months there will be some shortage of power during five months of the year, and if the shortages for the several months are summed, it will be found that the total shortage is equivalent to full power for about three-quarters of a month. The dotted line showing the average of months in order of flow indicates that there will be a shortage for the same period, but that the aggregate shortage is nearly three times that shown by the average of calendar months.

If, now, instead of a developed plant, it be desired to consider the development of a new plant under the not uncommon rule of development, up to that flow that can as an average be counted on for eight months of the year, the diagram shows that it will be safer to develop by the dotted curve, since the eighth month by this record is lower than by the record of calendar months, and it is also plain that it will be best to compute the shortage by the record of months in order of flow.

The record by calendar months would show a proper development corresponding to a run-off of 1.17 inches, while the curves showing the months in order of flow indicate that the development should be for 1.09 inches, a not very great difference. But if the stream be developed for a flow of 1.17 inches, the calendar record indicates a shortage aggregating only fourteen days of full power, while the record arranged in order of flow indicates a shortage aggregating nearly two months of full power, or about four times the shortage shown by the calendar arrangement. Even with a development of only 1.09 inches of run-off, the months arranged in order of yield show a shortage aggregating 1.7 months of full power.

This, it will be understood, is an average condition, but it will be well to examine what may occur in a minimum year. The record of the lowest year in the 15 recorded, is shown on the diagram, and indicates that whether the development be for 1.17 inches or 1.09 inches, there will be eight months in which there will be less than full power. And if the development be for 1.17 inches, the aggre-

gate shortage will be equivalent to 4.6 months of full power. The record further shows that this may approximately occur for two or three years in succession. As this period may very likely accompany a period of business depression, it must be fully taken into account in advising the utilization of a given water-power.

The diagram for the Sudbury drainage area shows the same general condition, but the difference is less marked. If developed on a basis of the calendar month record, the shortage shown by the calendar month diagram aggregates 1.67 months of full power as against 2.2 months shown by the diagram of flow arranged in order of volume.

If the stream is developed on a basis of the lower curve, there will be a shortage aggregating two months of full power. As before, the minimum year shows a shortage extending over eight months; and if the stream be developed by the calendar record, this shortage will aggregate 5.2 months of full power; while, if developed by the record arranged by months in order of flow, the shortage will still aggregate nearly five months of full power.

It is seen from these considerations that the far more reliable method of arranging run-off records for determination of power when there is to be no large storage on a stream, is to arrange the monthly records in the order of flow rather than by calendar months. But even this is very far from the most desirable method. Particularly in the low months is the record of a whole month affected by the run-off of one or two days during or immediately following heavy storms. So that the monthly record never shows less than the power available in the stream, and practically always shows more power than can be used, since during the two or three days which bring up the total flow of a month the discharge is far in excess of that that can be used, and the greater portion of the water goes to waste.

The smallest unit of time which it is probably wise to consider is the day. Only a few daily records were available for the preparation of this paper. The best that were at hand were the records of six years of flow on the Perkiomen, the years being from 1887 to 1893, inclusive, excepting the year 1892, which was lacking. Judged by its monthly flow, the record of which was available, the year 1892 was perhaps the lowest of the seven years, while the

year 1899 was one of the two highest years observed in fifteen. The omission of the year 1892, therefore, from the record leaves the average daily flow for this period too great, but for the purpose of comparing monthly and daily records the omission is perhaps not serious.

Selecting these six years, and treating them as has been already done for the fifteen-year period of the Perkiomen, and considering for the time being only the power available for the particular plant assumed previously, namely, one requiring 170 cubic feet per second or 1¼ inches of run-off from the drainage area, the calendar month arrangement shows (Fig. 3) that there will be a shortage of power for one month only, aggregating seven days of full power, while the arrangement by months in order of flow shows that there will be a shortage during four months, aggregating about one month and thirteen days of full power, or nearly six times as much power to be supplied by steam as is indicated by the calendar month record.

But how is it when the daily record is examined? For this examination the daily flow of each year has been arranged in order of magnitude. The resulting record for the lowest year, the highest year, and the average for the six years is shown on Fig. 4. Considering again the particular plant already assumed, using 170 cubic feet per second, the diagram shows there will be a shortage extending over two hundred and eight days, or about 6.8 months instead of four months as by the monthly method, and that this shortage will aggregate about 3.2 months of full power, nearly thirteen times the amount of power to be supplied by the calendar month arrangement, and over twice that to be supplied as indicated by the monthly record arranged in order of flow.

Even this average does not tell the exact truth, because when the record of any day in any year exceeds 170 cubic feet per second all the flow above this volume tends to lift the average of the six years, but is itself unavailable for power; and to get at the exact truth, it is necessary to make an average in which the flow in every year for each day that has a larger value than 170 cubic feet per second, must be taken as only 170 cubic feet per second, until the flow of that year in which the low flow extends furthest reaches 170 cubic feet per second. Making such an average for these six

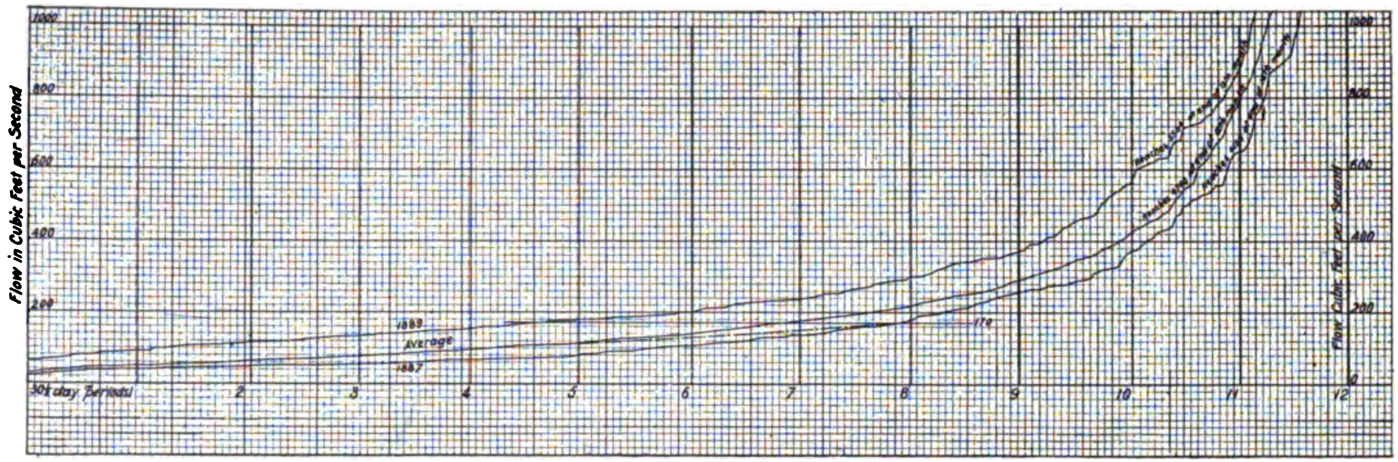

Flow in Cubic Feet per Second
1000
800
600
400
200
1889
Average
1887
170
30 day Periods
2
3
4
5
6
7
8
9
10
11
12
0
Flow Cubic Feet per Second

FIG. 4.

years, it is found that the shortage will extend over two hundred and thirty-seven days instead of two hundred and eight days, giving an aggregate of about one hundred days of full power to be supplied by steam.

The addition to the aggregate determined from the straight average is not large, but the cost of supplying this power is not in proportion to the amount of power supplied. If the steam plant were run constantly with not too large variations in power, the cost would perhaps be somewhat nearly proportional to the amount of power supplied, being determined largely by the quantity of fuel consumed. But where the amount of power to be supplied is very small, the labor item becomes relatively large, and the cost per horse-power hour becomes relatively greater than during those days when the steam plant is run more or less nearly up to its full capacity.

The general purpose of this paper has been to show that for streams on which there is little or no storage, the only proper way to estimate the power available for any development is to estimate it from the daily rather than the monthly flow; and to show the very considerable discrepancy that exists between the commoner method by monthly flows and the suggested method by daily flows.

FILTER OPERATIONS, INVESTIGATIONS FOR ADDITIONAL SUPPLY AND CONSTRUCTION OF NEW FILTER AT LAWRENCE, MASS.

BY MORRIS KNOWLES, CHIEF ENGINEER DEPARTMENT OF FILTRATION, PITTSBURG, PA.; M. F. COLLINS, SUPERINTENDENT OF WATER WORKS, LAWRENCE, MASS.; AND ARTHUR D. MARBLE, CITY ENGINEER, LAWRENCE, MASS.

[*Read February 12, 1908.*]

INTRODUCTION.

As is explained in the title of this paper, it is the intention, *first*, to consider the history of the operations of the old filter, which was started in September, 1893. Also, in connection with this, to tell about the changes in methods of operation and new items of construction or equipment for the old filter:

Second, to give a history of the agitation for obtaining a new supply, both by driven wells and by additional filter construction:

Third, to give a brief description of the filter and some of the items of cost which have entered into it.

HISTORY OF FILTER OPERATIONS.

In order that the history may be continuous, the method of consideration has been the same as in a paper presented before the American Society of Civil Engineers, June 5, 1901, by Morris Knowles and Charles Gilman Hyde (Trans. Am. Soc. C. E., Vol. XLVI, December, 1901). Furthermore, for the purpose of making the comparison more convenient, the numbers used to designate the present tables are the same as those given in that paper.

Population. The first table presented is called No. 1, giving the population of Lawrence, Mass., for the past seven years.

TABLE No. 1.

POPULATION OF LAWRENCE, MASS.

Date.	Enumeration by	Population.
1900	United States census.	62 559
1901	Estimated.	64 050
1902	"	65 580
1903	"	67 150
1904	"	68 750
1905	Massachusetts census.	70 050
1906	Estimated.	73 320
1907	Local census.	76 600

It is to be noticed by this table that the city has grown to a marked degree, an average of 3.2 per cent. per year. The increase is especially noticeable during the last two years, and is undoubtedly due to the completion of two large and important mill buildings in the city which has increased the number of operatives.

The need for additional water supply facilities, already somewhat evident, became markedly so as soon as it was known that these manufacturing concerns were to increase. It is an interesting study to notice how by strenuous methods, with the lack of means for supplying plenty of water, the use of this commodity per inhabitant was kept down to an unusual degree. It is quite probable that this will very soon increase with a greater amount of water available. The decrease is noticed in Table No. 4, and is graphically shown in Fig. 1, giving the use per inhabitant as ordinates with the per cent. of services metered as abscissas; the years being given for each point.

GENERAL DESCRIPTION.

The character of the water supply of the city of Lawrence, and of the Merrimac River, from which that supply is taken, is so well known that no extended description will be attempted at this time. Briefly stated, the watershed of the river has an area of 4 630 square miles and contains a population of over 500 000. Probably 60 per cent. of this population live in cities, the sewage from which is discharged in a crude state into the river. In 1901 it was estimated that in the driest times the proportion of sewage to the river water amounted to one gallon in every forty flowing past the city of Lawrence.

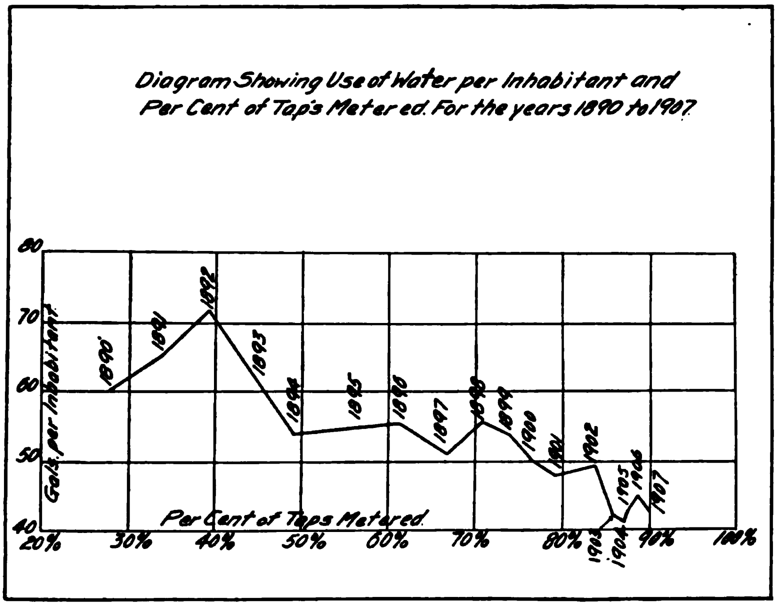


FIG. 1.

From the time of the completion of the original water works in November, 1875, to the fall of 1893, the city had been supplying this water, without purification, to its citizens.

In 1892 and 1893, after repeated outbreaks of typhoid fever, and a discussion lasting a year or more, the city took the advice of the State Board of Health and constructed a filter bed, 2½ acres in area, for the purification of its water supply. The details of this bed have been so completely covered in the paper before referred to, and so often considered in the reports of the State Board of Health, that a further description is needless.

In regard to the matters of operation, very little change has been made except in the building of the cross walls, which have divided the filter into three parts and made possible a scraping of one part while the other two are in use filtering water. There has been a change made in the method of handling the sand, throwing the dirty sand from the lower drive to the washer directly, without teaming, and this has saved some expense.

TABLE No. 4.

AVERAGE DAILY QUANTITY OF WATER PUMPED IN MILLION GALLONS, AND AVERAGE HOURS OF PUMPING PER DAY, AT LAWRENCE, MASS., FOR EACH MONTH, FROM 1901 TO 1907.

Month.	1901.		1902.		1903.		1904.		1905.		1906.		1907.	
	Quantity Million Gals.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.
January....	3.0	19.5	3.6	27.1	3.0	22.2	2.7	24.3	2.9	24.2	3.0	21.9	2.9	24.0
February...	3.1	20.7	3.2	25.3	2.7	21.4	2.8	22.6	2.3	21.0	3.0	23.6	2.8	23.4
March......	2.8	17.8	4.0	25.7	2.8	21.6	2.9	22.6	2.5	22.7	2.9	23.7	2.3	20.8
April.......	2.9	17.3	3.8	23.6	2.7	18.4	3.1	23.5	3.0	23.3	2.8	21.7	3.1	23.6
May........	2.8	16.5	3.0	19.7	3.2	21.2	3.2	20.4	3.4	22.9	2.8	19.5	3.4	24.9
June.......	3.3	20.7	3.4	22.7	2.9	19.7	2.9	21.6	3.3	21.3	3.6	23.8	3.9	26.4
July........	3.7	22.6	3.5	21.9	3.0	20.3	3.0	20.3	3.4	22.5	3.2	21.3	3.8	26.2
August.....	2.9	17.3	3.2	20.6	2.7	23.2	2.8	16.8	3.4	21.5	3.8	25.2	3.9	25.8
September..	3.6	21.5	3.1	20.3	2.7	25.7	2.8	17.7	3.4	19.1	3.7	25.6	3.6	24.1
October....	3.1	20.6	3.2	20.9	3.0	19.2	2.6	17.3	3.0	19.7	4.2	26.5	2.9	19.4
November..	3.0	21.1	3.1	23.6	2.5	18.5	2.4	21.1	2.9	19.6	3.4	24.6	3.2	26.3
December...	3.0	22.1	3.2	21.2	2.7	22.2	2.6	22.9	2.9	20.3	2.9	26.2	3.2	25.5
Average per day for year......	3.1	19.1	3.4	22.5	2.8	21.2	2.8	20.7	3.0	21.6	3.3	23.1	3.3	24.2

Hours per day is sum of high and low service.

There have been times when the water in the river has not been high enough to flow by gravity to the filter, and at such times it was necessary to resort to pumping to supply water to the filter. Since January, 1900, an 8-inch centrifugal pump has been used to pump water from the filter surface in order to drain it more rapidly when preparing for cleaning. At no time has the filter been operated intermittently, with intention, since the data published in the American Society of Civil Engineers paper above referred to. The hours of pumping per day have also increased, so that the opportunities for air entering the sand have been somewhat lessened.

Use of Water. In Table No. 4 there are given, in comprehensive form, the average daily pumpage by months, including both services, and the average number of hours per day during which the

TABLE No. 5.

AVERAGE TEMPERATURES OF AIR AT LAWRENCE, MASS. ALSO THE MAXIMUM AND MINIMUM FOR EACH MONTH FROM 1901 TO 1907.

Month.	1901.			1902.			1903.			1904.			1905.			1906.			1907.		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
January	23.4	47	-2	23.2	54	2	24.8	48	-6	17.2	42	-23	20.2	47	-8	31.9	66	4	22.6	55	-12
February	20.3	46	2	26.0	48	0	28.0	60	-8	17.8	46	-13	18.0	44	-13	26.3	56	-5	17.1	49	-18
March	34.0	58	18	42.3	64	24	42.6	76	18	31.9	67	-1	33.0	67	4	29.0	54	4	34.3	72	-6
April	44.2	76	40	47.6	74	36	46.5	83	21	43.0	71	20	45.0	68	20	45.6	76	23	41.6	75	23
May	55.0	86	44	57.2	88	40	58.9	90	31	60.4	89	36	56.0	84	33	56.6	90	33	52.0	82	29
June	68.6	96	52	64.1	89	53	60.2	86	38	63.0	91	38	64.6	90	39	65.5	87	40	63.9	94	39
July	73.4	94	60	67.9	92	58	70.1	96	51	69.8	89	49	72.0	94	51	71.2	89	47	71.6	92	53
August	70.8	90	64	66.8	92	60	63.8	84	47	66.5	87	45	67.8	89	46	72.2	92	50	68.0	95	46
September	64.2	92	42	61.8	92	48	63.4	93	34	60.2	79	30	60.4	80	34	63.4	89	36	62.0	87	38
October	52.2	78	33	51.4	80	32	51.0	74	26	47.1	68	21	50.8	79	24	51.0	71	28	46.8	72	20
November	34.4	68	12	43.4	75	28	36.7	73	9	34.8	56	8	38.0	63	11	38.9	66	17	39.2	60	19
December	27.9	62	2	24.4	50	1	24.2	52	-14	20.7	46	-4	30.6	58	3	24.8	48	-4	32.4	62	13
Average	47.4			48.0			47.5			44.4			46.4			48.0			46.0		
Maximum		96			92			96			91			94			92			95	
Minimum			-2			0			-14			-23			-13			-5			-18

pumps were operated. As the high-service pump is only operated a few hours each day, it will be seen that in recent years the use of water during the winter months has necessitated almost constant pumping.

Temperatures. Table No. 5 contains the statistics of the temperature of the air at Lawrence, which are given for the purpose of showing the effect that this factor has upon the use of water. It will be particularly noticed that the warm winter of 1905–6, during the months of December, January, and February, aided quite a little in saving the city of Lawrence from the disgrace of pumping raw river water into the mains.

Quantity Filtered. There does not seem to be any marked difference in the quantities filtered between scrapings as compared with the earlier results, and this is probably due to the fact that there are many other factors which enter into a consideration of this problem; for it is thought that the under-drains still continue to clog and one would naturally expect lesser and lesser yields. The data obtainable upon this point are presented in Table No. 6.

TABLE No. 6.

LONGEST PERIODS BETWEEN COMPLETE SCRAPINGS OF THE LAWRENCE FILTER FOR THE SEVEN YEARS FROM 1901 TO 1907.

No.	Last Day of Complete Scraping.	First Day of Next Complete Scraping.	Length of Period in Days.	Total Quantity in Million Gallons between Scrapings.
1	March 22, 1901	April 17, 1901	27	80
2	April 20, 1901	May 28, 1901	39	121
3	Aug. 30, 1901	Sept. 25, 1901	27	103
4	Sept. 27, 1901	Oct. 28, 1901	32	99
5	Oct. 31, 1901	Nov. 25, 1901	26	83
6	March 13, 1902	April 1, 1902	20	90
7	April 2, 1902	May 1, 1902	29	120
8	May 2, 1902	June 17, 1902	44	155
9	June 20, 1902	July 10, 1902	21	80
10	July 13, 1902	Aug. 5, 1902	24	100
11	Dec. 4, 1902	Jan. 1, 1903	29	93
12	April 26, 1904	May 12, 1904	17	58
13	Nov. 27, 1904	Dec. 18, 1904	22	58
14	April 7, 1905	April 27, 1905	21	69
15	April 30, 1905	May 21, 1905	22	74
16	May 25, 1905	June 12, 1905	19	74
17	June 15, 1905	July 9, 1905	25	86
18	Dec. 6, 1905	Dec. 27, 1905,	22	64
19	April 28, 1906	May 21, 1906	24	72
20	March 28, 1907	April 21, 1907	25	78
21	May 11, 1907	May 30, 1907	20	74
22	Aug. 21, 1907	Sept. 23, 1907	34	138
23	Sept. 27, 1907	Oct. 21, 1907	25	87

Scraping. Regarding the records of scraping, which are presented in Tables Nos. 7 and 8, there is but little to be said; the average numbers seem to vary about as they did before, with an indication that the total amount of scraping removed is somewhat less than previously. It is possible that this is in part due to the lessened opportunity for scraping and a greater amount being removed each time. There is certainly a much better understanding of the necessity of regularity in scraping than previously existed, and this uniformity was shown in the later scrapings in the tables previously presented.

TABLE No. 7.

RECORDS OF SCRAPINGS OF THE LAWRENCE FILTER, ARRANGED BY BEDS FOR EACH YEAR, 1901–1907.

Bed.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	14	14	9	10	14	16	13
2	13	14	9	10	14	16	14
3	13	14	9	10	14	16	15
4	13	13	9	10	13	16	15
5	13	14	9	10	14	16	16
6	13	15	9	10	13	16	16
7	13	15	9	10	15	16	15
8	13	15	9	9	14	16	15
9	13	15	9	9	14	16	15
10	13	13	9	10	14	17	14
11	12	13	9	10	14	17	16
12	13	12	10	10	13	17	16
13	12	13	10	10	14	17	16
14	12	13	9	10	14	17	16
15	12	13	9	10	13	17	16
16	14	13	9	10	13	17	16
17	13	14	9	10	14	17	16
18	13	14	9	10	16	16	13
19	12	13	9	10	16	16	13
20	12	12	9	10	16	16	15
21	12	13	9	10	16	16	14
22	11	15	7	10	16	16	14
23	11	15	7	10	16	16	14
24	11	14	7	10	15	16	14
25	11	13	7	10	15	16	14
Total	312	342	219	247	360	408	371
Average	12	14	9	10	14	16	15

TABLE No. 8.

RECORD OF SCRAPINGS OF THE LAWRENCE FILTER, ARRANGED BY MONTHS, FOR THE YEARS 1901 TO 1907.

Months.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
January	25	15	22	20	23	42	33
February	20	22	16	29	24	25	23
March	31	58	25	34	46	25	45
April	25	25	34	25	50	50	25
May	25	25	21	25	25	16	42
June	25	25	8	14	25	25	33
July	28	25	13	11	21	33	25
August	27	36	5	0	16	42	42
September	25	27	25	17	25	33	25
October	35	50	0	8	25	42	25
November	19	25	34	48	47	42	28
December	27	25	16	16	33	33	25
Totals	312	358	219	247	360	408	371
Averages	26	30	18	21	30	34	31

TABLE No. 9.

DEPTH OF SAND IN INCHES REPLACED AT CROWN OF EACH BED OF THE LAWRENCE FILTER FOR YEARS 1901–1907.

Beds.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	10.5	8.8	10.7	4.2	9.5	8.8	3.8
2	13.9	11.5	11.1	4.3	9.2	9.3	6.5
3	15.6	12.0	11.4	4.0	10.4	10.0	8.0
4	15.0	9.8	11.9	5.7	10.7	9.3	7.5
5	14.3	9.7	10.0	6.3	10.5	8.9	7.3
6	14.4	7.3	11.8	5.9	10.3	8.8	8.3
7	14.0	10.5	9.5	6.3	7.2	9.0	6.0
8	13.0	10.0	9.5	6.0	6.9	8.8	8.8
9	10.5	9.8	10.2	6.7	6.8	8.5	5.0
10	9.0	6.5	9.8	2.8	7.0	7.8	11.5
11	8.4	4.0	10.9	3.0	7.1	8.3	12.8
12	10.1	4.0	11.0	3.2	6.7	10.5	9.0
13	10.9	4.0	11.5	6.8	6.5	10.8	8.8
14	8.5	4.0	12.7	7.0	7.5	11.0	9.5
15	9.0	4.0	12.0	4.7	7.3	10.8	7.5
16	9.2	4.0	12.3	4.5	7.7	9.0	9.0
17	11.8	4.0	11.7	4.0	8.5	8.5	9.5
18	12.5	4.0	12.5	5.1	5.5	10.3	7.2
19	8.8	4.0	13.8	4.9	5.9	10.3	7.0
20	4.5	4.0	14.9	5.4	6.2	11.0	9.8
21	7.2	4.0	14.5	5.7	6.0	10.8	8.8
22	6.8	4.0	15.2	6.3	5.9	11.0	11.2
23	7.3	4.0	15.1	7.8	5.5	11.1	12.0
24	8.0	4.0	14.8	6.4	5.0	10.0	9.2
25	8.4	4.0	11.7	4.9	5.2	10.5	8.5
Averages	10.4	6.0	12.0	5.3	7.4	9.7	8.0

Sanding. In the matter of resanding the filter, as shown in Table No. 9, there is not the same uniformity. We find that there has been a less total amount of new sand added each year. This has probably been due to the fact that, anticipating a new filter and some changes in the design of the old, it was not thought best to resand too large a quantity and have this to remove before going ahead with the new work.

The loss of head has not been regularly recorded in recent years and is not given here.

Draining. Table No. 12 gives a tabulation of the number of times the filter was drained, and although, as previously stated, there has been no intent to operate the filter intermittently, it gives an idea of the number of times it was possible for air to enter the pores of the sand.

COST OF ADDITIONAL CONSTRUCTION.

In addition to the cost items mentioned upon page 287 of the American Society of Civil Engineers' paper, previously mentioned, there have been additional items of construction carried on during recent years, *viz.*, the building of a new ice conveyor, new sand washer, and paving of driveway and slope. The most important, however, was the erection of the dividing walls, which were built in the year 1902. All of these items are given in Table No. 13, their total cost being $10 500, bringing the total cost of construction, not allowing for interest or depreciation, to $90 880. (See Plate VI. of Mr. Collins' paper.*)

TABLE No. 13.

ADDITIONAL CONSTRUCTION AT LAWRENCE FILTER FOR THE YEARS 1901–1907.
(Amounts given to nearest ten dollars.)

1901.	Widening roadway, paving, etc	$2 370
	New concrete work at slopes	500
1902.	Dividing walls, piping, etc	6 770
	New ice elevator	900
	Total	$10 540
Previous additions, 1894–1900		14 880
Original cost		65 460
	Total cost to end of 1907	$90 880

* "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288.

TABLE No. 12.

NUMBER OF TIMES WHEN THE LAWRENCE FILTER WAS DRAINED, 1901 TO 1907.

	1901.	1902.*			1903.			1904.			1905.			1906.			1907.		
		W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.
Total........	72	27																	
		2	2	2	15	15	15	19	16	17	25	18	22	23	20	21	17	18	17
Average per month.....	6		2.4			1.25			1.4			1.8			1.75			1.4	

* Division walls not completed until October 29, 1902. Previous to this time, in 1902, filter was drained 27 times. Letters to designated parts of the filter are: W, west portion; M, middle portion; E, east portion.

TABLE No. 14.

ITEMIZED STATEMENT OF COST OF MAINTENANCE OF THE LAWRENCE FILTER FOR THE YEARS 1901–1907.

Items.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
Scraping..............................	$1 570.00	$1 990.00	$1 130.00	$1 400.00	$1 810.00	$1 870.00	$1 740.00
Scraping and sanding..................	1 010.00	530.00	1 000.00	570.00	1 020.00	930.00	990.00
Conveying.............................	850.00	1 180.00	730.00	850.00	1 070.00	980.00	1 250.00
Washing...............................	970.00	340.00	1 220.00	460.00	470.00	960.00	850.00
Removing of snow and ice..............	2 900.00	3 670.00	2 740.00	4 400.00	3 780.00	2 620.00	3 250.00
General...............................	570.00	1 130.00	980.00	1 000.00	1 630.00	2 500.00	3 460.00
Total.................................	$7 870.00	$8 840.00	$7 800.00	$8 680.00	$9 780.00	$9 860.00	$11 540.00
Per million gallons...................	6.94	7.14	7.56	8.41	8.92	8.22	9.67
Total minus snow and ice..............	4 970.00	5 170.00	5 060.00	4 280.00	6 000.00	7 230.00	8 290.00
Per million gallons...................	4.38	4.18	4.91	4.15	5.47	6.03	6.95
Special work and repairs..............	740.00	1 090.00		1 550.00	1 160.00		
Total pumpage for year in million gallons,	1 134	1 238	1 031	1 031	1 096	1 203	1 193

COST OF OPERATION.

General. The costs of operation and maintenance of the Lawrence filter were among the first to be thoroughly analyzed and published. Although the later figures exhibited but few differences (except perhaps there is a general downward tendency until the last two years), it has been thought advisable to present all of these factors, beginning with the year 1901, in order to bring these items to date. The heavier cost of operations per million gallons of the last two years is to be explained by the additional draft upon the filter capacity.

The present figures have not been looked up with the detail care employed in making up Table No. 14, on page 288 of the American Society of Civil Engineers' paper; but, as the methods of accounting were quite well established by the year 1900, it is believed that the figures now presented and taken directly from the reports of the Water Board are reliable and useful for all of these purposes of comparison. It will be noticed that figures have been presented to the nearest ten dollars.

Scraping Costs. The method of hand scraping is now so well understood that we will not attempt to give, in detail, a description of this, but, for the purpose of comparison there is presented in Table No. 15 a statement of the bed scrapings per year, together with the cost per bed and the cost per million gallons of water filtered. It is gratifying to notice that recently there has been a tendency toward a lower cost per bed, and the only reason why this has not been lower per million is undoubtedly the general lessened yield per unit between scrapings. (See Plate I, Fig. 1, of Mr. Collins' earlier paper.)

TABLE No. 15.

STATEMENT OF THE TOTAL NUMBER OF BEDS SCRAPED PER YEAR, TOGETHER WITH THE COST PER BED PER SCRAPING AND PER MILLION GALLONS FILTERED AT THE LAWRENCE FILTER, FOR THE YEARS 1901–1907.

Years.	Number of Bed Scrapings.	Cost of Scraping.	Cost per Bed for Scraping.	Cost per Million Gallons of Water Filtered.
1901.....	312	$1 570	$5.03	$1.38
1902.....	342	1 990	5.82	1.61
1903.....	219	1 130	5.16	1.10
1904.....	247	1 400	5.67	1.36
1905.....	360	1 810	5.03	1.65
1906.....	408	1 870	4.60	1.56
1907.....	371	1 740	4.68	1.46
Average	323	1 644	5.14	1.44

Washing Costs. As was previously mentioned, there has been but little change in this work except to add an additional washer in order to save some of the cost of conveying. Also, it has been arranged to throw sand from the driveway to the washer itself. Both of these have lessened to some extent the cost per cubic yard, and it is a pleasure to record that there is a general downward tendency in this factor. The details of this classification of accounts are given in Table No. 16. (See Plate I, Fig. 1; and also Plate I, Fig. 2, of Mr. Collins' earlier paper.)

TABLE No. 16.

DETAIL COSTS OF SAND WASHING OPERATIONS AT LAWRENCE FILTER FOR THE YEARS 1901 TO 1907.

Year.	Cost of Operations.			Cubic Yards Washed.	Cost per Cubic Yard.
	Labor.	Bills.	Total.		
1901............	$870	$100	$970	2 024	$0.48
1902............	340		340	885	.38
1903............	1 170	50	1 220	3 046	.40
1904............	440	20	460	1 170	.39
1905............	470		470	1 500	.31
1906............	670	290	960	2 877	.33
1907............	850		850	2 192	.39

Snow and Ice Costs. There is but little need to comment upon these items of cost, which are given in Table No. 14; the method remains the same and the expense is fully as great as ever, much in excess of the interest on a sum of money needed to cover the present filter, and a yearly tax of from $2.50 to $4.00 per million gallons. This excessive expense for the three winter months of the year is an exorbitant one, which should not be endured any longer than is absolutely necessary. (See Plate II of Mr. Collins' earlier paper.)

RESULTS OF FILTRATION.

Chemical. In the matter of chemical results there is but little change from the previous determinations. It appears that the color in the effluent is somewhat higher than during the previous six years, as is also chlorine, in both river water and effluent.

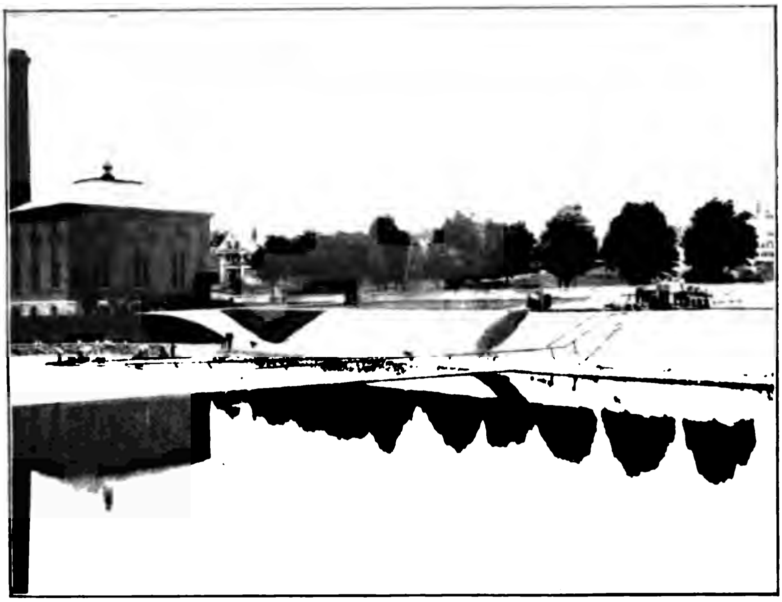


FIG. 1. Transporting Scraped Sand from Filter to Washer.

FIG. 2. Site of Filter, showing Work on Embankment, Jan. 28, 1906.

TABLE No. 17.

RESULTS OF CHEMICAL ANALYSES OF APPLIED MERRIMAC RIVER WATER AND EFFLUENT FROM LAWRENCE FILTER FOR THE YEARS 1901 TO 1907 (PARTS PER MILLION).

Year.	Yearly Rainfall in Inches.	Color.			Ammonia. Free.			Ammonia. Albuminoid.			Chlorine.		
		River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	45.58	4.1	3.5	15	0.109	0.078	28	0.190	0.077	59	2.1	2.1	0
1901	45.53	5.1	4.6	10	0.111	0.103	7	0.226	0.102	52	2.5	2.5	0
1902	46.88	4.7	4.9	—4	0.081	0.091	—12	0.200	0.095	52	2.4	2.6	—18
1903	38.09	4.1	4.2	—3	0.09	0.098	—9	0.194	0.082	58	2.8	2.9	—4
1904	38.83	3.9	4.4	—13	0.126	0.125	1	0.216	0.092	57	3.2	3.3	—3
1905	35.32	4.1	4.7	—15	0.133	0.122	8	0.240	0.109	55	3.3	3.6	—9
1906	39.71	3.8	4.0	—5	0.128	0.105	7	0.211	0.089	56	3.5	3.5	—6
1907	37.25	3.9	3.9	0.0	0.146			0.237			3.2	3.3	—3
Average, 7 years	40.23	4.2	4.4	—4	0.116	*0.107	*0.3	0.218	*0.095	*55	3.0	3.1	—6
Average 6 previous years	38.85	4.7	3.8	11.6	0.089	0.092	—3.4	0.199	0.094	52.8	2.2	2.4	—9

(Continued on following page.)

TABLE No. 17 — *Continued.*

Year.	Hardness.			Nitrogen.						Oxygen Consumed.		
				Nitrites.			Nitrates.					
	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	12	16	—33	0.002	0.001	50	0.11	0.38	—260	4.3	2.4	44.2
1901	12	17	—42	0.002	0.001	50	0.15	0.40	—167	5.7	3.6	36.8
1902	12	14	—17	0.001	0.000	100	0.13	0.28	—115	5.4	3.8	29.7
1903	14	20	—43	0.002	0.001	50	0.13	0.32	—146	4.8	3.2	33.3
1904	17	21	—24	0.003	0.000	100	0.16	0.40	—150	5.4	3.7	31.5
1905	13	18	—38	0.003	0.001	67	0.16	0.38	—143	6.2	4.2	32.3
1906	11	14	—27	0.003	0.001	67	0.14	0.34	—127	5.8	3.6	38.0
1907	11	17	—55	0.003			0.14			6.3		
Average, 7 years	13	17	—35	0.002	*0.0007	*72	0.14	*0.35	*—141	5.7	*3.7	*29
Average 6 previous years	14	21	—50	0.002	0.001	50	0.14	0.40	—190	4.2	2.8	33

* Average for six years, figures for 1907 not obtainable at this date.

The same may also be said in regard to the nitrogen determinations, except the nitrates. In fact, there seems to be a gradual increase in the organic impurities in the river water, and this is also seen in the bacterial determinations. Table No. 17 gives the general chemical determinations, in the form of averages for each year, together with the percentage removed for each constituent and the averages for whole seven-year period, compared with average of the previous six years.

Bacterial. It appears there has been an increase of the bacteria contained in the river in the last seven years, but it is gratifying to note that there is no increase in the numbers found in the filtered water. In fact, it may be asserted with safety that, in general, numbers are lower than ever, with an accompanying greater degree of purification.

There is, however, one notable fact, and that is that there does not seem to be a further reduction of bacteria in the passage of the water through the pipe system of the town, and the tap at City Hall very frequently shows bacteria no lower, and sometimes a few higher, than in the effluent from the filter.

A truer indication, however, of the work of the filter is shown by the coli determinations, and it is gratifying to note that the numbers of times that these organisms were found in one cubic centimeter of the filtered water is low.

DEATHS FROM TYPHOID FEVER AND GENERAL DISEASES.

By many the true benefit of the filter is considered to be best represented by the number of cases of and deaths from typhoid fever, and by the total death-rate of the community. There are some other factors in Lawrence, however, which are likely to produce typhoid fever, among which may be mentioned the polluted canal water supply; also the cases by importation and contact, and secondary infection from these. These causes are not, however, anywhere near as strong in Lawrence as in some communities, but we are reminded by the recent investigations in Washington, D. C., not to place too much reliance on the typhoid fever death-rate.

In order that we may have these figures at hand, there are given in Table No. 21, the number of cases and deaths from typhoid fever

TABLE No. 18.

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent.	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1900.							
January	12 800	110	99.1	83	89	41	15
February	12 100	73	99.4	52	57	10	0
March	5 000	36	99.3	50	316	8	0
April	3 300	27	99.2	28	43	0	0
May	3 200	70	97.8	23	50	40	0
June	1 250	68	94.6	43	184	17	0
July	3 900	35	99.1	39	59	0	0
August	7 700	17	99.8	12	101	20	0
September	19 200	18	99.9	27	179	14	0
October	15 500	72	99.5	50	34	0	0
November	16 800	58	99.7	60	127	12	0
December	5 600	64	98.9	40	108	37	12.5
Average	8 970	54	99.4	43	87	17	2.3
1901.							
January	5 600	61	98.9	34	92	11.1	37.03
February	2 500	24	99.0	32	82	13.04	0.0
March	8 900	50	99.4	26	69	17.64	0.0
April	1 400	15	99.0	17	34	0.0	0.0
May	1 400	8	99.4	9	20	0.0	0.0
June	3 000	58	98.0	25	22	25.0	0.0
July	1 760	11	99.4	12	11	0.0	0.0

August	1 580	18	98.9	14	7	0.0	0.0
September	1 760	15	99.1	9	9	0.0	0.0
October	1 900	22	98.8	11	10	0.0	0.0
November	1 300	7	99.5	6	5	0.0	0.0
December	5 100	22	99.6	26	8	0.0	0.0
Average	3 017	26	99.1	18	10.2	10.5	3.1
1902.							
January	7 300	47	99.4	58	21	4	0
February	7 400	44	99.4	51	45	4	0
March	4 500	61	98.6	64	20	6	0
April	4 200	75	98.2	66	16	0	0
May	3 300	30	99.1	26	28	0	0
June	2 700	32	98.8	40	55	0	0
July	3 700	35	99.9	57	161	0	0
August	20 900	324	98.4	112	219	14	0
September	15 300	23	99.8	66	104	0	0
October	10 000	105	98.9	125	53	0	0
November	4 300	25	99 3	103	83	0	0
December	7 000	109	98.4	96	72	8	8
Average	10 300	76	99.3	72	73	4	1
1903.							
January	12 500	58	99.5	71	32	0	0
February	7 000	33	99.5	75	23	4	0
March	4 100	20	99.5	38	40	8	4
April	2 200	12	99.5	19	24	8	8
May	4 100	18	99.6	24	58	0	0
June	18 200	14	99.9	45	141	0	0
July	3 800	18	99.5	27	68	25	0
August	4 000	17	99.6	50	66	20	0
September	38 400	20	99.9	41	141	0	0
October	40 300	29	99.9	85	178	0	0
November	5 300	32	99.4	33	70	88	0
December	14 500	110	99.2	85	95	4	4
Average	12 900	32	99.7	49	78	4.2	1.7

TABLE No. 18 — *Continued.*

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent.	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1904.							
January	10 100	70	99.3	55	62	4	0
February	7 200	55	99.2	36	51	12.5	8.3
March	4 000	33	99.2	46	23	0	0
April	2 700	20	99.3	57	12	0	0
May	3 100	16	99.5	24	53	0	0
June	5 600	22	99.6	44	70	0	0
July	8 000	11	99.9	35	125	25	25
August	3 500	14	99.6	135	34	40	0
September	19 400	16	99.9	45	129	0	0
October	5 600	26	99.5	60	93	0	0
November	15 600	90	99.4	43	110	10.5	10.5
December	17 900	75	99.6	65	115	4	0
Average	8 600	37	99.6	55	73	8	3.6
1905.							
January	14 200	110	99.2	70	101	20	0
February	14 800	55	99.6	33	125	0	0
March	10 300	55	99.5	55	98	0	0
April	3 600	170	95.3	60	38	8.7	4.3
May	1 900	12	99.4	34	26	0	0
June	9 600	9	99.9	23	60	0	0
July	3 900	55	98.6	75	57	0	0

August	19 500	37	99.8	51	272	33.3	17.6
September	13 500	44	99.7	53	189	10	0
October	39 800	110	99.7	65	169	0	0
November	8 700	70	99.2	70	160	0	37.5
December	11 500	24	99.5	46	122	0	0
Average	12 600	63	99.5	53	155	6	4.1
1906.							
January	8 600	52	99.4	55	105	7.4	7.4
February	6 400	38	99.4	23	80	0.0	0.0
March	5 400	22	99.6	26	57	3.7	0.0
April	3 200	19	99.4	26	31	4.5	0.0
May	1 600	16	99.4	26	51	0.0	0.0
June	1 000	6	99.4	60	59	25.0	0.0
July	6 200	18	99.7	70	143	0.0	0.0
August	4 100	13	99.7	35	1 160	0 0	25.0
September	2 600	11	99.6	60	61	0.0	0.0
October	5 200	12	99.8	110	85	0 0	20.0
November	1 900	11	99.4	22	44	0 0	0.0
December	2 900	20	99.3	16	153	0.0	0.0
Average	4 092	20	99.6	36	165	3.4	4.4
1907.							
January	3 900	33	99.2	45	101	9.1	0.0
February	3 000	18	99.4	20	54	0.0	0.0
March	3 200	19	99.4	39	58	3.4	0.0
April	2 200	14	99.4	19	25	0.0	0.0
May	700	9	98.7	12	42	0.0	0.0
June	950	10	98.9	8	69	0.0	0.0
July	2 600	20	99.2	48	62	20.0	0.0
August	3 000	29	99.0	19	168	0.0	0.0
September	5 700	22	99.6	38	87	25.0	0.0
October	1 400	10	99.3	16	105	0.0	0.0
November	3 300	22	99.3	54	140	4.4	0.0
December	3 400	26	99.2	23	100	3.3	0.0
Average	2 800	19	99.3	28	84	5.5	0.0

in the city of Lawrence, together with the rate per 10 000 and percentage of cases resulting in death; the total death rate in the city of Lawrence; the typhoid fever and total death-rates in the state of Massachusetts are also given as far as obtainable. The averages of the same data by years given in the former paper, for the six years prior to construction and the six years following construction, are shown for comparison with the average of the last seven years. The last figure shows remarkable uniformity, except for two years, 1903 and 1907,* the death-rate being kept well down, and it is indeed a gratifying result. It is also interesting to note the reduction in whole state, as well as the reduction in general death-rate in both state and city.

TABLE No. 21.

REPORTED CASES OF TYPHOID FEVER AND THE DEATHS RESULTING THEREFROM FOR THE YEARS 1901 TO 1907; ALSO THE DEATHS FROM ALL DISEASES AND SAME FACTS FOR THE STATE OF MASSACHUSETTS.

Year.	Number of Cases.		Number of Deaths.		Percentage Resulting in Death.	All Diseases, Death-Rate per 10 000, Lawrence.	Typhoid Death-Rate, Mass.	All Diseases, Death-Rate per 10 000, Mass.
	Total Reported.	Per 10 000 Population.	Total Reported.	Per 10 000 Population.				
1901	100	15	12	1.8	12	170.8	2.0	168.6
1902	102	15	11	1.6	11	177.3	1.9	162.1
1903	149	21	20	2.9	13	178.4	1.8	161.3
1904	61	9	10	1.4	16	165.9	1.6	154.7
1905	98	14	15	2.1	15	195.9	1.9	167.7
1906	105	14	13	1.7	12	182.8	1.6	166.1
1907	129	17	21	2.7	16	188.9	...	.....
Average	106	15	15	2.0	14	180.0	...	.....
†Average 6 years previous	188	43	53	12.0	28	.....	4.0	198.3
‡Average 6 years after	84	15	14	2.6	18	.....	2.6	183.3
Per cent. reduction	55	65	72	78	35	.....	...	.....

† Previous to construction of filter.
‡ After construction of filter.

STUDIES FOR ADDITIONAL SUPPLY.

The successive moves made by the Water Board and the city councils, before an appropriation was granted for construction of

* See discussion by M. F. Collins.

the new filter, form an interesting record of the ways of municipal activities. For some years the officials of the Water Department had been on the anxious seat, due to the lack of filter capacity, and many times the reservoir has been almost drained in the winter time.

In looking back over the history it seems almost incredible that this critical state of affairs should not have been recognized by every one and that each willing shoulder should not have been put to the wheel in making for progress and in obtaining something which could be accomplished within a reasonable time rather than to experiment upon ideas or conjecture.

1902 Agitation. The annual report of the Water Board for 1901 was the first to call attention to the imperative demand for additional filter capacity. Upon July 2, 1902, a joint meeting of the city councils was held to consider the need of the new filter, which meeting was addressed by Hiram F. Mills, civil engineer, member of the State Board of Health. The suggestions then made were that the old filter be covered and that a new one be located to the west of the old. It is interesting to note that this period is just about ten years after the first appropriation for the old filter. The meeting did not result in anything tangible. Councils inspected the old filter upon July 9 and, as the suggestions did not seem to be heeded, Mr. Mills thought advisable upon July 10 to transmit a letter of warning.

On July 11, 1902, the Water Board voted to construct the dividing walls which had been recommended by Mr. M. F. Collins, then "care-taker of the filter," in the annual report for 1900, and again advocated during this year. It was decided not feasible to cover the old filter at this time, but it was also voted to place meters on all services. On the 11th of the month, the city council voted $5 000 for the walls, and on the 25th, the contract was awarded to Joseph Wagenbach & Son for $3 322.78. The total cost of the work complete, including that done by the department, was $6 767.60.*

On August 7, the State Board of Health addressed a letter to the mayor and city councils advising that more complete steps

* See paper on "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288, for description and illustrations.

should be taken, as the walls would be of insignificant advantage, and other means of increasing the supply were urgently needed. The work of building walls was completed, so as to use the beds in sections on October 8, 1902, and advantages in the operation resulted, with less anxiety in the winter season.

1903 Agitation. The question of additional filter area was again recognized and came to the front in the first of the year 1903. The Water Board once more called attention to the condition and said that something should be done at once. Early in March it was arranged to have plans and specifications prepared for the new filter, and on March 14 surveys were begun by the city engineer for the purpose of securing the necessary information and data upon which to plan this work. During the latter part of the month a request was made of the city councils for an appropriation of $60 000. Notwithstanding all of this agitation and discussion, however, and the recommendations of leading citizens as to the necessity, the city councils withheld their approval, on the grounds of insufficient funds.

1904 Agitation. During the winter of 1903–4 conditions became so critical, the reservoir was so very low, and the accumulation of ice upon the filter so great that the yield grew less than ever. The State Board of Health, on February 17, warned the Water Board that dire results would follow if steps were not taken to husband the supply and curtail all possible waste. It was recommended, if stringent restrictions failed to give relief, that the Board should ascertain if water could not be obtained from either of the surrounding towns. Conferences were held for this purpose, but no action resulted thereform. Thereupon, the president and superintendent of the Water Board appeared again before councils, with a request that money be furnished to provide for building a filter according to the plans which had already been approved by the State Board of Health. Restrictive measures were helpful, as is shown by the lessened use of water.

Shortly after this, communications were received from two filtration companies, advocating certain special types of filters at lesser cost. There was considerable delay in considering the various plans and the impossibility of securing a new filter before winter was realized.

The driven-well proposition was first suggested about this time; a communication was received, April 21, 1904, offering to supply 2 000 000 gallons daily from wells to be driven on the south side of the river, nearly opposite the pumping station; however, nothing was done. The city government next endeavored, through the Water Board, to obtain water from adjacent towns, which request was made in the month of September, 1904. The result was a refusal of each town, on the ground that such action would be illegal.

1905 Agitation. The same condition continued during the winter of 1904–5, barely enough water being filtered to supply the daily need. There was no reserve in cases of emergency, but fortunately no extraordinary drain taxed the filter. Early in January of this year the joint standing committee on water works of the city council, together with the Water Board, were constituted a committee to determine whether a suitable supply could be obtained by driven wells. These investigations continued in many places for some months and lasted into the fall of the year. It is surprising, notwithstanding the correct knowledge of the usefulness of the filter and in face of opinions of the city engineer and superintendent of water works that suitable well water could not be obtained in sufficient quantities, and with only two days' supply in the reservoir on March 14, 1905, that public sentiment allowed such dillydallying in this important matter.

Wells were drilled in many places, — up the Merrimac River near Pine Island, in the easterly portion of the city at Sow Brook, on the south side of the Merrimac River as far south as Cold Spring, and in the Shawsheen Valley in Andover. Some of the wells did not produce sufficient water and some contained too much carbonic acid or too much iron. For one reason or another none of the sources were found suitable. It seemed, however, to be against public opinion to give up the idea of well water, even when the drilling concern had acknowledged the improbability of success, and the investigations were continued and more money spent. Many reports were received from well-drillers, from interested persons, and from the State Board of Health; the latter finally concluded that none of the places considered were acceptable for the purpose of obtaining a water supply. The total cost of these

experiments and studies was $5 764.44, and they extended over a period of eight months and into the late fall.

During the early spring, and about the time it was first thought of obtaining water from driven wells, the water supply committee of the legislature held a hearing, at which it was recognized that conditions at Lawrence were deplorable. Although the hearing developed these conditions, the city government was given one week to act. Upon failure to so do, the legislature ordered the city of Lawrence, through its mayor and board of aldermen, to construct, within a year, an adequate filter, or temporarily obtain water from the surrounding towns. This legislative act is so unusual that it is given as follows:

CHAPTER 389 OF THE ACTS AND RESOLVES OF MASSACHUSETTS LEGISLATURE OF 1905.

An act to provide for an increased water supply for the city of Lawrence.

Be it enacted, etc., as follows:

SECTION 1. The city of Lawrence, acting through its mayor and aldermen, shall forthwith increase the capacity of its works for filtering the water of the Merrimack River to such an extent as to insure at all times a sufficient quantity of water for the use of the public in that city, or it may take water from any spring, pond, or well, in Andover, North Andover, Tewksbury, or North Reading; provided, that no source of water supply for domestic purposes shall be taken or used under this act without the approval of the State Board of Health, and that the location of all filter galleries and wells, and the design of filters, shall be approved by the State Board of Health; and provided, further, that if water shall be taken directly from any pond or stream other than the Merrimack River, it shall be used only for the period of one year from the date of the passage of this act, and only in such quantities as the State Board of Health may deem necessary.

SECT. 2. Said city is hereby authorized and directed to raise and appropriate, in such manner as the city council shall determine, such sums of money as shall be requisite for carrying out the provisions of this act; and, if the city council shall so determine, the city may incur indebtedness for the purpose of obtaining money to such an amount as may be necessary for carrying out the provisions of this act, and may issue bonds, notes, or scrip therefor.

SECT. 3. The city of Lawrence shall pay all damages to property that may be sustained by any person or persons by the taking of the waters of any stream or pond as authorized by this act, or insofar as the said city may diminish the flow in any stream or pond, or by the taking of any land, rights of way or easements, or by the erection of dams or the construction of any aqueducts, waterways or other works for the purposes of this act; and such damages shall be assessed and determined in the manner provided by Chapter 48 of the Revised Laws.

SECT. 4. The towns of Andover, North Andover and Methuen, or any one of them, are hereby authorized to contract with the city of Lawrence for a supply of water upon such terms and for such periods of time, not exceeding one year from the date of the passage of this act, as may be agreed upon by the mayor and aldermen of said city and by the selectmen of the town entering into the contract.

SECT. 5. The supreme judicial court shall have jurisdiction to enforce the provisions of this act.

SECT. 6. This act shall take effect upon its passage. (Approved May 10, 1905.)

Inquiries made during the early summer and formal requests made to each of the towns of Andover and North Andover in the late fall, brought the same results as before, namely, that no relief was to be obtained from these sources. The prevalent belief among the officials of these places seemed to be that such temporary arrangements would be used to secure permanent rights.

In August, 1905, it was suggested that the cleaning of the under-

drains of the filter, such as had been done at a prior date, in 1899 and in 1900, would be a benefit. A few drains were examined, disclosing about the same character of clogging material as was noticed when this work was done before. The project was abandoned, however, for fear that disturbance at this time would be unwise.

1906 Results. The winter of 1905–6 was less severe than the few previous ones, so that the conditions did not reach such a critical stage. In the spring of 1906, however, the agitation for a new filter was renewed, after more legislative and public hearings, in which the conditions and need of a new filter were made plain. The legislature, through its Committee on Water Supply, discussed taking action, but waited, giving the city opportunity. After some discussion, upon March 28, 1906, the city council authorized a loan of $70 000 for the construction of a filter. Upon May 25, 1906, bids were received and contract awarded to Michael O'Mahoney, a long-time Lawrence citizen, for the construction of a filter, at an estimated total of $47 543.

The work was started on May 28, 1906, with every prospect that the filter would be in use by November 15, the date set for its completion. Many delays, however, occurred, as the contractor had to abide by an ordinance of the councils to use local labor entirely; and in the early part of November it became evident that completion on time was not possible, and the city councils gave the contractor permission to employ labor from outside the city. Winter came on, however, with the filter uncompleted, and as the winter was a severe and cold one, there was no alternative left but to again apply to the neighboring towns for a temporary supply. In order that the previous objection of illegality could not now be brought up, there was an enabling act passed by the legislature authorizing such temporary use.

Temporary Supply. This action in obtaining water from the surrounding towns is an interesting example of what can be done under pressure. Upon December 16, 1906, the Water Board called attention to the danger and the immediate necessity for securing an additional supply. Upon December 18 there was a conference with the officials of North Andover, and a special election was ordered upon January 1, 1907. The vote, however, was strongly

against supplying the city of Lawrence with water. A special election was authorized in Andover upon January 7, and the vote was almost unanimous in favor of giving aid. The water from Andover was turned into the city main on Friday, January 11.

On February 5 attention was again called to the low water in the reservoir, and upon February 6 a conference was held in Boston, between a local committee from the Lawrence city government and the Water Supply Committee of the legislature, together with members from the State Board of Health. Recognizing the necessity, a bill was introduced and passed in the legislature upon February 7, and signed immediately by the governor, which authorized the town of North Andover to temporarily supply the city of Lawrence with some water from Great Pond. Upon February 14, water from the town of North Andover was turned into the piping system of the city of Lawrence, and, with this help, the water in the reservoir gained and was not again lowered to the danger limit. There was about 50 000 000 gallons obtained from Andover, at a total cost of about $4 500. There was about 37 000-000 gallons obtained from North Andover, at a cost of about $5 500, making the total expense to the city of Lawrence for this lack of forethought and lack of paying attention to proper advice, $10 000, which includes cost of connections.

On April 3, 1907, occurred an accident which caused a set-back in the progress. This was due to a section of the filter roof collapsing, which will be considered in detail by Mr. Sanford E. Thompson.

The entire filter was completed and water turned on November 5, 1907, about one year behind time. At first the filter was run at a slow rate and it was about two months, or January 4, before the State Board of Health allowed the water to be used as a drinking supply by the people, and it is advised that for some time the rate of filtration shall not exceed 1 000 000 gallons per day.

DESCRIPTION OF THE NEW LAWRENCE FILTER.

General. This filter is located directly west of the old one; a portion of it is south of the boiler house and comes close to the foundation. It extends westward, covering an area of about three quarters of an acre. It also extends out into the river bed

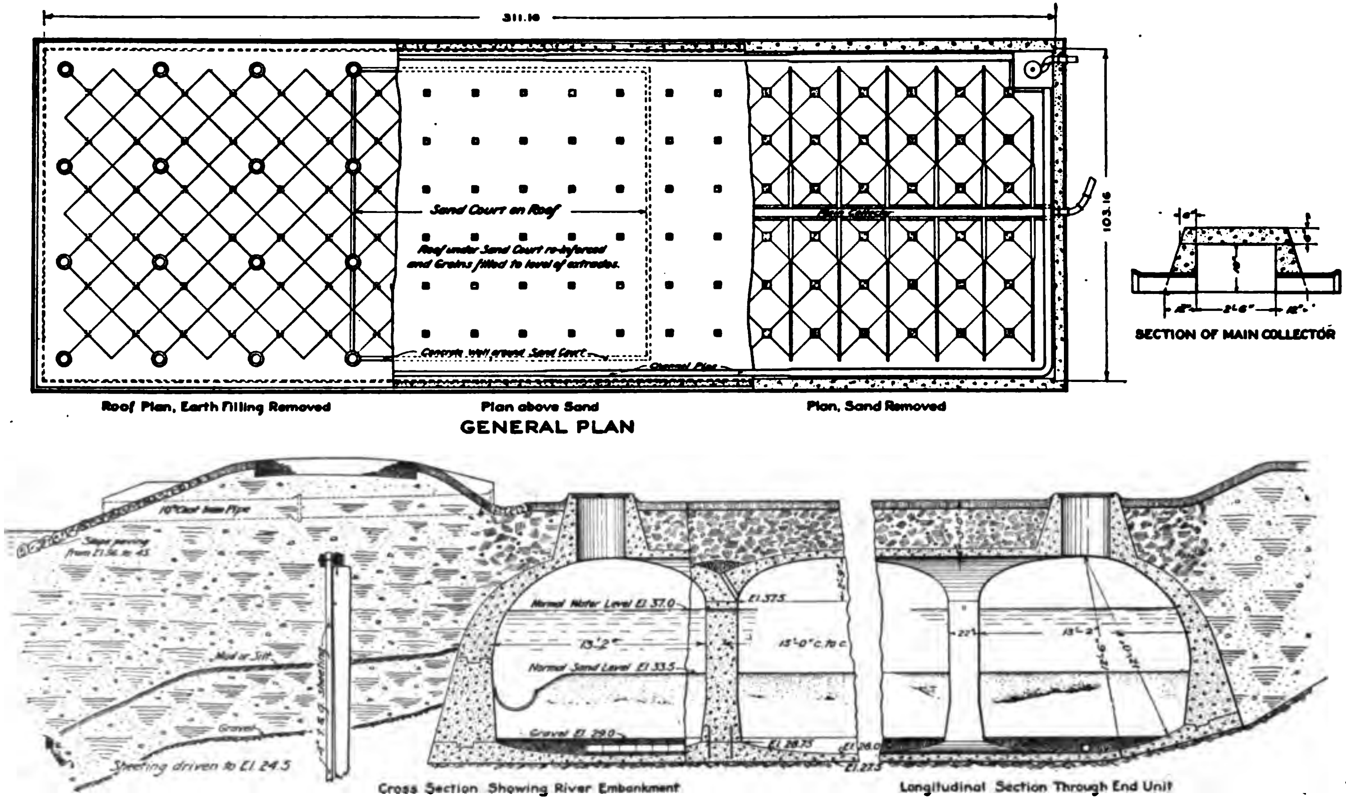

311.10
103.16
Sand Court on Roof
Roof under Sand Court re-inforced and Grains filled to level of extrados.
Concrete wall around Sand Court
Channel Pipe
Main Collector
Roof Plan, Earth Filling Removed
Plan above Sand
Plan, Sand Removed
GENERAL PLAN
SECTION OF MAIN COLLECTOR
10" Cast Iron Pipe
Slope paving from El. 36. to 45
Mud or Silt
Gravel
Sheeting driven to El. 24.5
Normal Water Level El. 37.0
Normal Sand Level El. 33.5
Gravel El. 29.0
El. 37.5
15'-0" c. to c.
El. 28.75
El. 28.0
El. 27.5
Cross Section Showing River Embankment
Longitudinal Section Through End Unit

FIG. 2.

and a new embankment was constructed along the shore of the river from the material of excavation. (See Plate I, Fig. 2, and Plate II, Fig. 1.) The amount of excavation was about 35 000 cubic yards, and the concrete amounted to about 2 900 cubic yards.

The filter is 21 bays long and 7 bays wide, the bays being 15 feet from center to center of the piers. A general plan and sections are shown in Fig. 2. There are various manholes in the roof for the purpose of letting light into the filter and also to serve as ventilators. Originally it was intended to have the usual sand incline and entrance in the easterly end that has commonly been constructed for filters of this type. With the advances in the method of handling sand, it was thought that it would never be necessary to use wheelbarrows; therefore, a rectangular monitor entrance was constructed, by which it will be possible to have access into the filter. For the purpose of taking out sand that has been scraped it is proposed to use pipe lines in connection with the ejector system. In addition to this, and in order to provide for a storage place for sand upon the roof, an area of 6 bays each way, in the middle of the filter, was reinforced with cross lines of ¾-inch steel rods, spaced 9 inches apart, center to center, and also an additional amount of 3 inches of concrete was placed over the entire surface and leveled over the piers, with a filling of cinders 12 inches thick and a concrete pavement on top. Concrete walls were also placed about this area in order that the sand should be confined and not scattered over the sod which will cover the remainder of the roof. Sand will be returned through the openings in the roof. (See Plate II, Fig. 2.)

The river embankment has a core of sheeting in order to make it tight and to aid in keeping the water out during the construction. Some water was encountered in the bottom, but an 8-inch pump working part of the time was sufficient to take care of it. The sub-grade was generally of good material, especially when the ground was well drained. Some little trouble was occasioned in a few places in placing concrete on the bottom; these places were later thoroughly repaired. In order to take care of the upward pressure of the water whenever the filter may be drained while the river is high, gravel drains were laid to pipes all coming

FIG. 1. Cofferdam Construction and Excavation, August 9, 1906.

FIG. 2. Method of Reinforcing Roof for Storing Sand, July 5, 1906.

into one central pipe 24 inches in diameter and filled with coarse gravel. This pipe projects upward through the floor and through the bed of sand. This will allow the pressure under the floor to be relieved and the excess water to flow out over the surface of the sand in case such conditions occur.

Details. The details of the filter construction are those of the usual type of groined arch roof, with inverted groined floor, taking the load from piers spaced 15 feet apart. The roof is 6 inches thick at the crown, with a rise of 2 feet 9 inches and a depression at the piers of 20 inches. The floor is 6 inches thick midway between piers, with a greater thickness of 15 inches underneath the piers. The piers are 22 inches square, with chamfered corners, and battered below the sand line so that they are 30 inches square at the base. The water which collects upon the roof of the filter, and above on the slope, will be taken down through openings in the piers and be filtered.

Water is brought to the filter from the gate house which supplies the old filter through a 20-inch pipe, and in through a controlling valve operated by a float, upon the surface of the sand. In order to thoroughly distribute the water and not cause disturbance of the sand, half-channel pipes are placed along the sides of the filter to receive the water as it comes in the inlet channel. (See Plate V, Fig. 2.)

The main drain which takes the water away from the filter is a concrete structure of box shape, with vertical sides and a flat slab roof; it is large enough for a man to crawl through. Twelve-inch half-tile pipes enter this at the center of each bay and extend one bay toward the side walls. From this point there are 6-inch pipes entering these 12-inch half-pipes. (See Plate VI, Fig. 1.)

The filter sand is supported on the drainage gravel, which averages 1 foot in depth. The lower 7 inches ranges from about 3 inches to 1½ inches in size. The next 2½ inches in depth is of gravel running from 1½ inches to ⅜ inch. Above this there is 1½ inches of washed roofing or pea gravel running from ⅜ inch to a little smaller, followed by 1 inch of coarse sand. Gravel of the pea size was required to be washed before being placed; other gravel was found sufficiently clean. Filter sand was placed to an average depth of 4½ feet and, according to certain requirements which

were specified, was from about 0.22 to 0.28 millimeter in effective size. (See Plate VI, Fig. 2.)

Materials. The cement used on this work was Atlas Portland cement and was of the usual good quality. The results of the tests, grouped by weeks according to the period of setting, are given in Table No. 22.

The sand and gravel for making the concrete was obtained partly from the excavation, partly from the adjoining hillside, and partly from a nearby bank. It was generally good material with a slight tendency toward fineness and with some clayey material in the gravel. This, as will be pointed out by Mr. Thompson, may have had some slight effect upon the strength of the concrete.

The filter gravel was obtained partly from excavation and partly from a nearby bank on Hancock Street near the place where the filter material was obtained for the first filter. The filter sand was obtained from the same bank, and, to a considerable degree, was obtained without any washing, but simply by screening as it came from the bank. The analyses given in Table No. 23 show the condition of the sand and about what proportion was required to be washed. Table No. 24 also shows the time which it took water to pass through a sample of the sand contained in a standard tin, this being a quick means of determining whether the sand was suitable for filtering purposes. About five times per day a check was made upon general average samples of the whole body, by mechanical analysis. The State Board of Health made check determinations from time to time.

Costs. The canvas of bids for this work is given in Table No. 25, and shows the details of the prices bid by the six different contractors, also giving the engineer's estimate made prior to receiving bids. It is interesting to note that there are three bids which total below the engineer's estimate and three bids which run above this; also that the prices of the lowest bidder are about one half of the highest, with the average of the total costs of about $2 500 higher than the engineer's estimate. The greatest variations occur in the items of cofferdam, excavation, and concrete, and are about the same proportions as the variations in the totals.*

* A copy of the final estimate is given in Table No. 26.

FIG. 1. View of Barrel Arch and Outside Wall, Nov. 1, 1906.

FIG. 2. Forms for Piers and Vaulting, looking Northeast, Nov. 15, 1906.

FIG. 1. General View of Construction, looking East, Nov. 1, 1907.

FIG. 2. Piers and Forms for Vaulting, looking West, May 24, 1907.

FIG. 1. Outside Bay of Filter Interior, Aug. 29, 1907.

FIG. 2. Outside Bay of Filter, Sand in Place, showing Distributing Trough, Nov. 4, 1907.

FIG. 1. Main Collector, Laterals and Under-drainage System, Sept. 16, 1907.

FIG. 2. Three Layers of Filter Sand, also No. 4 Gravel, Oct. 15, 1907.

FIG. 1. Finished Surface of Filter Sand, Nov. 4, 1907.

TABLE No. 22.

TESTS OF ATLAS CEMENT USED IN LAWRENCE FILTER.
FOR WEEK ENDING DATE GIVEN.

One-Day Tests.

Mixed During Week Ending	Per Cent. of Water.	Time in Air, Days.	Time in Water, Days.	Per Cent. of Sand by Weight.	Tensile Strength.	No. of Samples.
Aug. 11, 1906.	18	0	1	Neat	350	9
Sept. 15, "	16	0	1	"	468	10
" 22, "	16	0	1	"	561	10
" 29, "	16	0	1	"	308	5
Oct. 6, "	16	0	1	"	380	15
" 13, "	16	0	1	"	388	5
" 20, "	16	0	1	"	362	15
" 27, "	16	0	1	"	326	5
June 8, 1907.	18	0	1	"	261	5
" 15, "	21	0	1	"	234	10
July 20, "	20	0	1	"	283	5
" 27, "	18	0	1	"	263	5
Average,					364	

Seven-Day Tests.

Mixed During Week Ending	Per Cent. of Water.	Time in Air, Days.	Time in Water, Days.	Per Cent. of Sand by Weight.	Tensile Strength.	No. of Samples.
Aug. 11, 1906.	18	1	6	Neat	688	6
Sept. 15, "	16	1	6	"	730	5
" 22, "	16	1	6	"	629	15
" 29, "	16	1	6	"	823	5
Oct. 6, "	16	1	6	"	790	5
" 13, "	16	1	6	"	813	10
" 20, "	16	1	6	"	653	5
" 27, "	16	1	6	"	738	15
Nov. 17, "	17	1	6	"	745	10
Aug. 11, "	24	1	6	300%	274	2
Sept. 22, "	24	1	6	300	148	5
June 1, 1907.	18	1	6	Neat	636	5
" 8, "	18	1	6	"	493	5
July 6, "	16	1	6	"	676	5
" 13, "	22	1	6	"	516	5
" 20, "	22	1	6	"	515	5
June 15, "	22	1	6	300	222	15
Average,				Neat,	687	
"				300%,	210	

Twenty-eight Day Tests.

Mixed During Week Ending	Per Cent. of Water.	Time in Air, Days.	Time in Water, Days.	Per Cent. of Sand by Weight.	Tensile Strength.	No. of Samples.
Aug. 10, 1906.	18	1	27	Neat	868	2
" 28, "	16	1	27	"	736	5
Oct. 5, "	16	1	27	"	913	5
" 26, "	16	1	27	"	838	10
" 28, "	16	1	27	"	749	5
Aug. 10, "	24	1	27	300	256	2
Sept. 21, "	24	1	27	300	235	5
Oct. 5, "	24	1	27	300	167	5
Average,				Neat,	818	
"				300%,	210	

TABLE No. 23.

MECHANICAL ANALYSES AND WATER TIME TESTS OF FILTER SAND FOR NEW LAWRENCE FILTER, 1907.

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
September.							
20........	1	Washed.	..	..	.70	.20	3.5
20........	2	"	..	..	.92	.26	3.5
20........	3	"	..	47	.90	.28	3.2
20........	4	"	1	8	.89	.23	3.8
21........	5	"	..	..	.90	.26	3.4
21........	6	"	..	..	.91	.26	3.5
21........	7	"	..	..	.95	.26	3.6
22........	8	Unwashed.	..	..	.72	.21	3.4
22........	9	"	..	..	.82	.23	3.6
22........	10	"	1	2	1.10	.25	4.4
22........	11	"	1	15	.82	.22	3.7
24........	12	Washed.	..	48	1.00	.26	3.8
24........	13	"	..	58	.92	.26	3.5
24........	14	"	..	..	.92	.24	3.8
24........	15	Unwashed.	1	21	.91	.23	3.9
24........	16	Washed.	1	9	.81	.22	3.6
25........	17	"	..	53	.97	.25	3.8
25........	18	"	1	16	.77	.24	3.2
25........	19	"	1	20	.82	.23	3.5
25........	20	"	..	54	.87	.25	3.4
25........	21	"	1	6	.93	.24	3.8
Average for week.....................				40	.88	.24	3.6
26........	22	Washed.	1	20	.71	.23	3.1
26........	23	"	1	14	.97	.25	3.8
26........	24	"	..	52	1.20	.31	3.9
26........	25	"	1	9	.84	.26	3.2
26........	26	"	1	14	.90	.36	3.4
26........	27	"	1	12	1.10	.25	4.4
26........	28	"	1	18	.76	.23	3.3
27........	29	"	1	32	.77	.25	3.1
27........	30	"	1	15	.71	.22	3.2
27........	31	"	1	30	.77	.22	3.5
27........	32	"	1	23	.68	.24	2.8
27........	33	"	1	22	.65	.23	2.8
28........	34	"	1	32	.52	.22	2.3
28........	35	"	1	5	.96	.26	3.7

TABLE No. 23 — *Continued.*

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
September.							
28........	36	Washed	1	27	.77	.23	3.2
28........	37	"	1	35	.52	.21	2.4
28........	38	"	1	25	.81	.25	3.2
28........	39	"	1	30	.82	.22	3.7
28........	40	Unwashed.	1	58	.44	.19	2.3
28........	41	Washed.	1	58	.44	.21	2.1
28........	42	"	1	34	.72	.22	3.2
30........	43	"	1	45	.70	.21	3.3
30........	44	"	1	20	.94	.22	4.2
30........	45	"	1	20	.72	.24	3.0
30........	46	"	1	10	.77	.24	3.2
30........	47	"	1	20	.73	.24	3.0
30.........	48	"	1	18	.72	.24	3.0
30	49	Vein.	..	..	.77	.26	3.0
October.							
1........	50	Washed.	1	25	.84	.24	3.5
1........	51	Unwashed.	1	25	.62	.23	2.7
1........	52	"	1	12	.74	.25	3.0
1........	53	Washed.	1	26	.81	.23	3.5
1........	54	"	1	20	.80	.24	3.3
1........	55	"	1	35	.85	.24	3.5
2........	56	"	1	35	.81	.22	3.6
2........	57	"	1	8	.93	.24	3.8
Average for week...............			1	21	.77	.25	3.1
3........	58	Washed.	1	19	.79	.24	3.2
3........	59	"	1	16	.90	.25	3.6
3........	60	"	1	2	.94	.25	3.6
3........	61	Unwashed.	1	10	.79	.24	3.2
3........	62	"	1	2	.86	.26	3.3
3........	63	"	1	2	.84	.26	3.2
3........	64	"	1	12	.82	.25	3.2
3........	65	Washed.	..	48	1.40	.31	4.5
3........	66	"	1	28	.77	.20	3.8
4........	67	Unwashed.	1	30	.64	.21	3.0
4........	68	"	1	15	.82	.25	3.2
4........	69	"	1	10	.82	.24	3.4
4........	70	"	1	18	.99	.24	4.1
4........	71	"	1	8	1.00	.27	3.3

TABLE No. 23 — *Continued.*

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
October.							
5........	72	Washed.	..	57	.92	.26	3.5
5........	73	"	1	5	.83	.24	3.4
5........	74	Unwashed.	..	55	1.00	.27	3.7
5........	75	"	1	20	1.20	.27	4.4
6........	76	"	1	27	1.30	.24	5.4
6........	77	"	1	8	1.20	.25	4.8
7........	78	Washed.	1	18	.91	.24	3.7
7........	79	"	1	5	.91	.23	3.9
7........	80	"	..	44	1.50	.27	5.5
7........	81	Unwashed.	1	8	1.40	.26	5.3
9........	82	"	1	30	1.30	.25	5.2
9........	83	"	..	55	1.30	.28	4.6
9........	84	"	1	20	1.30	.26	5.0
Average for week...............			1	12	1.02	.25	4.0
October.							
10........	85	Unwashed.	1	2	1.30	.31	4.1
10........	86	"	1	16	1.10	.25	4.0
10........	87	"	1	7	1.50	.31	4.5
11........	88	Washed.		57	1.30	.27	4.8
11........	89	Unwashed.	1	30	.93	.22	4.2
11........	90	"	1	5	1.10	.23	4.7
12........	91	"	1	13	.97	.25	3.8
12........	92	"	1	5	.90	.24	3.6
14........	93	"	1	2	1.40	.25	5.6
15........	94	"	..	40	1.00	.31	3.2
Average for week...............			1	6	1.15	.26	4.3
October.							
18	95	Unwashed.	1	5	1.10	.28	3.9
18........	96	"	..	57	.94	.28	3.3
19........	97	Bank.	..	..	.90	.25	3.6
19........	98	"	..	..	1.00	.25	4.0
19........	99	"	..	..	.83	.22	3.7
20........	100	Washed.	1	34	.74	.22	3.4
20........	101	"	..	..	.95	.26	3.6
21........	102	"	1	10	.86	.24	3.5
21........	103	Bank.	..	..	.91	.23	3.9
22........	104	Washed.	..	..	.86	.26	3.3
22........	105	"	..	..	.89	.26	3.4
22........	106	"	..	..	.89	.26	3.4
22........	107	Bank.	..	..	.96	.24	4.0
22........	108	"	..	..	.87	.29	3.0
23........	109	"	..	..	.80	.23	3.5
23........	110	Washed.	..	..	.92	.26	3.5
23........	111	Bank.	..	..	.81	.22	3.6
23........	112	Washed.	..	..	.91	.26	3.5
Average for week...............			..	..	.90	.25	3.6

TABLE No. 23 — *Continued.*

Date. October.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
27........	113	Bank.	1	10	.92	.27	3.4
27........	114	Washed.	..	57	1.00	.27	3.7
28........	115	"	..	55	1.05	.28	3.7
28........	116	"	1	27	.79	.22	3.6
28........	117	"	1	55	.95	.24	3.9
29........	118	"	1	..	.86	.25	3.4
29........	119	"	1	2	1.10	.27	4.0
29........	120	"	..	52	1.00	.27	3.7
29........	121	"	1	16	.90	.23	3.9
29........	122	"	1	17	.87	.23	3.6
29........	123	"	1	10	.88	.25	3.5
29........	124	"	1	32	1.00	.25	4.0
29........	125	"	1	30	1.00	.25	4.0
29........	126	"	1	33	.97	.25	3.8
29........	127	"	1	35	.92	.24	3.8
29........	128	"	2	10	.66	.19	3.4
30........	129	"	1	28	1.00	.25	4.0
30........	130	"	1	22	.96	.25	3.8
30........	131	"	1	42	.79	.23	3.4
30........	132	"	1	41	.93	.24	3.8
30........	133	"	1	39	.82	.23	3.5
30........	134	"	1	26	.77	.21	3.6
30........	135	"	1	44	.89	.25	3.5
30........	136	"	1	29	.89	.24	3.7
31........	137	"	1	16	.89	.24	3.7
31........	138	"	1	12	.91	.24	3.8
31........	139	"	1	40	.76	.23	3.3
31........	140	"	1	20	.86	.24	3.5
31........	141	"	2	7	.79	.22	3.5
31........	142	"	2	19	.76	.21	3.6
31........	143	"	1	42	.82	.23	3.5
31........	144	"	1	26	.82	.23	3.5
31........	145	"	1	22	.94	.26	3.6
31........	146	"	1	25	.98	.26	3.7
31........	147	"	1	52	.77	.21	3.6
31........	148	"	1	40	.95	.26	3.6
31........	149	"	1	51	.87	.23	3.7
31........	150	"	1	25	.83	.23	3.6
31........	151	"	1	42	.84	.22	3.8
31........	152	"	1	33	.95	.25	3.8
31........	153	"	1	40	.92	.24	3.8
31........	154	"	1	47	.91	.25	3.6
31........	155	"	1	33	.84	.22	3.8
31........	156	"	1	40	.82	.22	3.7
31........	157	"	1	37	.87	.23	3.6
31........	158	"	1	40	.84	.23	3.6
31........	159	"	1	23	.97	.24	4.0
31........	160	"	2	11	.71	.21	3.3
Average......................			1	32	.90	.24	3.7

TABLE No. 24.

Water Test of Filter Sand for New Lawrence Filter.

Date.		No. of Samples.	Average Time. Min.	Average Time. Sec.	Minimum Time. Min.	Minimum Time. Sec.	Maximum Time. Min.	Maximum Time. Sec.	No. which were of Washed Sand.
September	20....	10	–	57	–	37	1	47	10
,,	21....	5	–	50	–	46	–	56	5
,,	22....	9	1	13	1	2	1	32	9
,,	24....	9	1	1	–	45	1	26	9
,,	25....	7	1	12	–	58	1	36	7
,,	26....	9	1	11	–	52	1	23	9
Average for week,		8	1	4	–	39	1	27	8
September	27....	10	1	18	–	56	1	32	10
,,	28....	8	1	34	1	7	1	55	8
,,	30....	6	1	21	1	10	1	45	6
October	1....	6	1	28	1	12	1	45	4
,,	2....	20	1	12	–	48	1	47	10
,,	3....	14	1	17	–	55	2	3	2
Average for week,		11	1	22	1	1	1	48	7
October	5....	10	1	13	–	50	1	45	0
,,	6....	26	1	25	1	–	1	52	7
,,	7....	18	1	18	–	42	1	45	7
,,	9....	23	1	18	–	45	1	56	4
,,	10....	47	1	21	–	48	1	58	4
Average for week,		25	1	19		49	1	51	5
October	11....	31	1	19	–	55	1	46	2
,,	12....	32	1	18	–	53	1	45	4
,,	13....	61	1	21	–	47	1	57	61
,,	14....	32	1	21	–	47	1	56	32
,,	15....	27	1	28	–	51	1	50	27
,,	16....	37	1	21	–	53	1	50	37
,,	17....	50	1	27	–	47	3	–	50
Average for week,		39	1	22	–	50	2	1	30
October	18....	42	1	17	–	40	1	50	42
,,	19....	38	1	18	–	40	1	58	38
,,	20....	19	1	29	–	47	2	14	19
,,	21....	31	1	26	–	38	2	50	31
,,	22....	44	1	29	–	34	2	22	44
,,	23....	47	1	25	–	42	2	22	47
,,	24....	49	1	31	–	37	2	28	49
Average for week,		39	1	25	–	39	2	18	39

TABLE No. 24 — *Continued.*

Date.		No. of Samples.	Average Time. Min.	Average Time. Sec.	Minimum Time. Min.	Minimum Time. Sec.	Maximum Time. Min.	Maximum Time. Sec.	No. which were of Washed Sand.
October	25....	42	1	34	–	47	2	24	42
,,	26....	58	1	31	–	52	2	19	58
,,	27....	31	1	41	–	44	2	16	31
,,	28....	9	1	42	1	35	1	58	9
,,	29....	10	1	43	1	35	1	57	10
,,	30....	10	1	43	1	35	1	59	10
,,	31....	34	1	29	–	59	1	48	34
November	1....	22	1	31	–	56	2	5	22
,,	2....	40	1	25	–	52	1	46	40
,,	4....	4	1	33	1	24	1	38	4
Av'r'ge last 10 dys.,		26	1	35	1	8	2	1	26

NOTE: Test made by placing 10 cubic inches of sand, closely measured in another tin, into a conical receptacle, having a screen at the base of 14 meshes to the inch. Testing receptacle was 3 inches in diameter at top, 2 inches in diameter at the bottom and 8 inches high. A coarse screen, of 6 meshes to the inch, was placed on top of the sand, water was then filled in the receptacle and the time of passage through the sand was noted. Acceptable filter sand allowed the water to pass through in from one minute to one minute and thirty seconds.

TABLE No. 26.

FINAL ESTIMATE OF CONSTRUCTION OF LAWRENCE FILTER, DECEMBER 1, 1907.

Item No.	Items.	Quantity.	Prices.	Amounts.
1	Cofferdam	Lump.	....	$3 600.00
2	Excavation	,,	....	11 550.00
3	Slope paving	1 210.5 sq. yds.	$2.50	3 026.25
4	Concrete in floors			
5	Concrete in walls	2 974 cu. yds.	5.57	15 562.58
6	Concrete in piers			
7	Concrete in roof			
8	Roof centers	32 305.6 sq. ft.	0.15	4 845.84
9	Cast-iron pipe	19.15 tons.	70.00	1 340.50
10	Cast-iron specials	4.24 tons.	100.00	424.00
11	Valves and appurtenances	Lump.	.....	500.00
12	Regulating and indicating apparatus	Lump.	.....	500.00
13	Structural work	15 304 lbs.	0.04	612.16
14	Tile drainage system	Lump.	.....	850.00
15	Filter gravel	902 cu. yds.	1.00	902.00
16	Filter sand	4 991 cu. yds.	0.60	2 994.60
17	Entrance	Lump.	.....	1 200.00
18	Extra work			1 538.18
	Total..........			$49 446.11

Total cost of filter, including printing, issuing of bonds, and engineering.......... $54 331.48

TABLE No. 25.

CANVASS OF BIDS FOR CONSTRUCTION OF LAWRENCE FILTER. RECEIVED MAY 30, 1906.

Item Number.	Item.	Quantities.	Engineer's Estimate.	M. O'Mahoney, Lawrence. (Successful Bidder.)	Coleman Bros., Boston, Mass.	Ward & Coombs, Lowell, Mass., and Dover, N.H.	Cole & Holland, Lawrence.	C. E. Trumbull & Co., Lawrence.	Bruno, Salomond & Petiti, Boston, Mass.
1	Cofferdam, etc.	Lump	$7 500.00	$3 600.00	$3 000.00	$10 052.00	$17 420.00	$7 000.00	$10 000.00
2	Excavation	Lump	14 500.00	11 550.00	15 000.00	16 000.00	21 000.00	33 000.00	27 000.00
3	Slope paving	900 sq. yds.	1.50	2.50	1.50	0.75	0.75	1.00	1.50
4	Concrete in floors	900 cu. yds.	7.50	5.57	6.00	8.00	6.00	6.50	8.00
5	Concrete in walls	900 cu. yds.	8.00	5.57	7.00	7.00	6.00	7.50	9.00
6	Concrete in piers	150 cu. yds.	10.00	5.57	8.00	8.00	6.00	9.00	10.50
7	Concrete in roof	950 cu. yds.	7.00	5.57	8.00	8.00	7.50	8.50	12.00
8	Arch centers	32 000 sq. ft.	0.10	0.15	0.10	0.10	0.13	0.10	0.10
9	Cast-iron pipe	20 tons	70.00	70.00	50.00	40.00	55.00	60.00	50.00
10	Cast-iron specials and flanged pipe	5 tons	100.00	100.00	125.00	80.00	100.00	100.00	80.00
11	Gates, valves, and appurtenances	Lump	500.00	500.00	600.00	400.00	300.00	500.00	500.00
12	Regulating and indicating apparatus	Lump	1 500.00	500.00	1 300.00	1 400.00	250.00	1 500.00	1 000.00
13	Structural work, etc.	11 000 lbs.	0.10	0.04	0.04	0.07	0.035	0.05	0.06
14	Tile drainage system	Lump	1 050.00	850.00	780.00	1 500.00	460.70	600.00	2 000.00
15	Filter gravel	800 cu. yds.	1.50	1.00	2.00	2.00	2.25	1.50	1.50
16	Filter sand	5 000 cu.yds.	1.60	0.60	1.00	1.00	1.00	1.25	1.50
17	Entrance	Lump	600.00	1 200.00	150.00	100.00	300.00	100.00	1 000.00
	Total	....	$64 500.00	$47 593.00	$54 545.00	$64 197.00	$72 175.70	$78 525.00	$85 085.00

The final return of the quantity of filter sand, after settling, was within 9 yards of the estimated quantity.

A detail study of the cost of the filter sand shows that two thirds of the sand was washed and that the remaining third passed examination after screening at the bank. The sand from the general run of the bank gave from 2½ to 4 per cent. finer than 0.13 millimeter, which was the minimum size allowed. After washing, there still remained from ½ to 1½ per cent. of this same fine material. It was thus estimated that about 3 per cent. was lost in washing, which checks very well with the count of the number of loads hauled from the bank.

No accurate data were kept as to the cost of the sand, but some general notes taken may be helpful. It was estimated that the sand was worth 10 cents a yard at the bank, and the cost of the screening, together with the cost of the hauling, added 40 cents. In addition to this there were 6½ cents more for general expenses, including spreading in the filter, making the total cost of the unwashed sand, 56½ cents per cubic yard, delivered in place at the filter. In the same way it was estimated that the cost of the washed sand was 76½ cents delivered in place at the filter. When the shrinkage in the water settlement is taken into account, which amounted to 4½ per cent., or a depth of 0.2 foot, these sums became respectively 59 cents and 80 cents. The bid price was 60 cents.

The cost of the filter sand exhibits in a typical way something about how near the contractor estimated what this work would cost him, and it is probable that upon many of the other items of the contract he made no greater amount of money. Perhaps he even lost. It is unfortunate that public work is frequently let to the lowest bidder because of an erroneous belief or public sentiment that if it is not done, there are ulterior and wrong reasons for doing otherwise. The letting of contracts to the lowest bidder, when he does not receive a sufficient amount of money to warrant his putting capital, equipment, and energy into the job, produces a slow rate of speed, which sometimes causes a municipality to lose in the end, and frequently work is unfortunately and badly delayed. This was the case at Lawrence, where the cost, during the winter of 1906–7, was $10 000 for water

purchased from other towns, and connections, which money could have been saved if this filter had been completed on time. There is no doubt that with energy, well-considered and well-directed efforts, this work could have been accomplished within the time set for its completion.

DISCUSSION.

MR. STEPHEN DEM. GAGE.* During the eleven years that I have been connected with the Lawrence Experiment Station, I have followed the work of the Lawrence filter and its effect upon the health and prosperity of the people of that city very carefully, and I have been very much interested in the able résumé of the subject which Mr. Knowles, Mr. Marble, and Mr. Collins have presented this afternoon. The construction of the Lawrence filter marks an important epoch in the history of municipal sanitation in the United States, in that it was the first filter constructed in this country for the express purpose of reducing the death-rate from a specific disease, typhoid fever. It marks also the first practical application of data obtained from the operation of experimental filters with a given water supply to the improvement of that water supply by filtration. That a reduction in typhoid fever would ensue from the introduction of filtered water in Lawrence was accurately predicted by the results obtained with experimental filters at the Lawrence Experiment Station in 1890 and 1891, and this prediction has been more than fulfilled. In addition, a very material reduction has occurred in the total death-rate of the city, a reduction so different in character from that gradual decrease due to increased appreciation of municipal sanitation which has taken place throughout the state of Massachusetts, and following so closely the introduction of filtered water, that it can only be explained by attributing it to the improvement in water supply. In tabulating the results of the national census of 1900, this decrease in the death-rate was made the subject of special inquiry by the chief statistician of the census bureau, who addressed a letter to the local health officials inquiring if some error had not been made in working up the vital statistics of the

* Biologist, Lawrence Experiment Station, Lawrence. Mass.

city which would account for the sudden drop in many of the death-rates after 1893, as he could conceive of no adequate reason for such a marked reduction.

In the accompanying diagram, Fig. 3, I have plotted the death-rates from all causes and from typhoid fever in both Lawrence and Massachusetts for the twenty-five years from 1881 to 1905. A study of the plotted curves reveals that during that period there has been a gradual decrease in both typhoid and in general mortality in Massachusetts. The Lawrence curves are characteris-

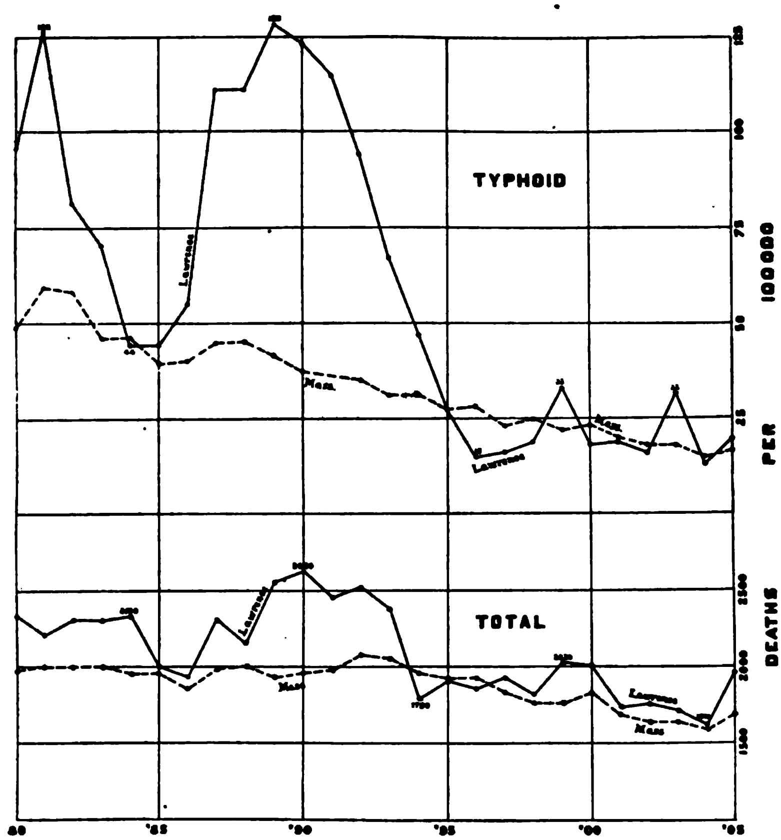


Fig. 3. Comparison of Death Rates in Lawrence and in Massachusetts during Twenty-Five Years.

tically different from the Massachusetts curves. Previous to 1890, the Lawrence curves have an upward inclination, denoting that the total number of deaths, and especially the deaths from typhoid fever, were increasing faster than the population. In 1891 and 1892 the people were warned of the dadger of drinking the city water and many adopted the precaution of boiling the water or began using spring water, and the curves assume a downward tendency from that time, which tendency was made permanent by the introduction of filtered water in 1893.

It will be noted that the typhoid death-rates for Lawrence after 1895 were lower than those for the whole state except in three years, and the cause of these few high points must be sought for outside of the filtered water supply, as Mr. Collins has explained.

It is usually considered that the material prosperity of any municipality is measured in part at least by the healthfulness of its population. Let us consider what effect the introduction of filtered water has had upon the prosperity of the city of Lawrence. It is usually accepted that the loss of a human life represents a loss in the earning capacity of a community of about $5 000. For every person who dies from typhoid fever there are ten who recover but whose illness has entailed a loss to the community of at least $100, or a loss of $1 000 for each death, so that the drain on the community is actually about $6 000 for each death from typhoid fever. During the ten-year period from 1881 to 1890, when unfiltered water was being used, the mean annual death-rate from typhoid fever was 90 deaths per 100 000. During the ten years from 1896 to 1905, when filtered water was in use, the mean yearly death-rate from typhoid fever was 20 per 100 000, an average annual saving of 70 lives per 100 000 by the decrease in this one disease. With an average population of 61 600 during these ten years, this means an actual annual saving of 43.12 lives represented by $6 000 each, or a net gain to the community of $258 700 per year. The average cost of filtration, including interest on the cost of the filter during the same period, was only about $12 000 per year, and the total cost of water-works maintenance, including interest and depreciation, was only about $110 000 per year. In other words, the introduction of filtered water into the city of Lawrence may be said to have caused a yearly saving to the com-

munity of about twenty times the cost of filtration and of more than twice the entire cost of supplying water. A similar computation might be based on the reduction in the total death-rate, when the annual saving would be found to amount to more than one and one-third million dollars, but the decrease in typhoid fever alone has yielded an ample return on the money invested in the filtration plant and fully warrants such extensions and improvements in the plant as are necessary to keep pace with a rapidly increasing population.

Mr. M. F. Collins. When Mr. Gage called your attention to the curved lines, showing the death-rate from typhoid fever in Lawrence before and after the building of the filter, the high points for the years 1903 and 1907 were especially noted. I feel that the increase in typhoid fever cases in the years 1903 and 1907 calls for some explanation. In 1903 the Lower Pacific Mill had 43 cases reported. The local Board of Health called the attention of the state board of health to the conditions existing at the above mill, and the state board delegated one of their corps of assistants to investigate and locate the cause if possible. It was found that the check valve which was placed between the city mains and their mill supply was leaking. The mill authorities were notified to place another check valve within a few feet of the other, which was done, and no further complaints were received from that source.

During the year 1907, in the Washington Mills, from January 28, to March 1, there were 48 cases of typhoid fever and 7 deaths from this mill alone, thus greatly increasing the number of cases for the year. After several of these cases had been reported, the local Board of Health investigated the condition of affairs there and insisted on the mill authorities providing better facilities for supplying pure drinking water for their help. After these improvements had been made this epidemic ceased and there has been no unusual number of cases there since. The following table gives the number of cases and deaths from typhoid fever and the tributary causes as far as they could be ascertained at the time.

TABLE No. 27.

Typhoid Fever for 1907.

Months.	Cases.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.	Deaths.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.
January	15	3		8	1	15	0					0
February	51		3	39	4	51	6			6		6
March	5	1	1	1	1	5	3			2		3
April	9		1	4	1	9	1					1
May	5			3		5	2			1		2
June	3			1		3	1					1
July	6			3		6	2					2
August	7	1		4		7	0					0
September	8	3		2	1	8	4	2				4
October	6			5	1	6	1			1		1
November	7			2	1	7	1					1
December	7	1	1	4		7	0					0
Total‡	129	9	6	76	10	129	21	2	0	10	0	21

* Canal Water. Persons employed in mills where canal water is used and who may have had access to that water.

† Spring Water. Persons who have used spring water exclusively.

‡ From January 28 to March 1 there were 48 cases and 7 deaths among the employees of one mill in this city, the Washington Mills.

INVESTIGATION OF COLLAPSE OF FILTER ROOF DURING CONSTRUCTION AT LAWRENCE, MASS.

BY SANFORD E. THOMPSON, CONSULTING ENGINEER, NEWTON HIGHLANDS, MASS.

The acquaintance of the writer with the Lawrence filters began towards the latter part of May, 1907, when, at the request of Mr. Knowles, he made an examination and report upon the collapse of a portion of the roof.

The investigation involved an examination of the concrete and the materials composing it, besides a general inspection of the condition of the filter after the collapse.

The concrete was laid in three divisions: First, the floor with its inverted groined arches; next, the columns, which were dowelled to the floor by two pieces of 1-inch iron pipe, projecting about 8 inches up into the column; and finally the roof of groined arches resting upon the columns and supported temporarily upon centering constructed in the usual manner for this type of work.

Various causes delayed the construction, and it was not until the 1st of November, 1906, that any concrete was laid upon the roof. At this time a length of 8½ bays of floor, out of a total length for the entire reservoir of 21 bays, and 8 rows of piers, had been placed.

Of the roof, 7½ bays were laid before the closing down for the winter, as follows:

November 2, 1906 — 2½ bays laid.
November 9, 1906 — 1 bay laid (from 2½ to 3½).
November 23, 1906 — 2 bays laid (from 3½ to 4½).
December 17, 1906 — 2 bays laid (from 5½ to 7½).

The forms for the last two bays (5½ to 7½) were up and ready for concrete on the last day of November, but they waited until the middle of December to get a temperature as high as 28° F. in the morning with prospect of a good day.

As many of you will remember, the fall and winter of 1906–7 were unusually cold, and as this had an important bearing upon the failure, Fig. 1, a curve of the temperature from November 1,

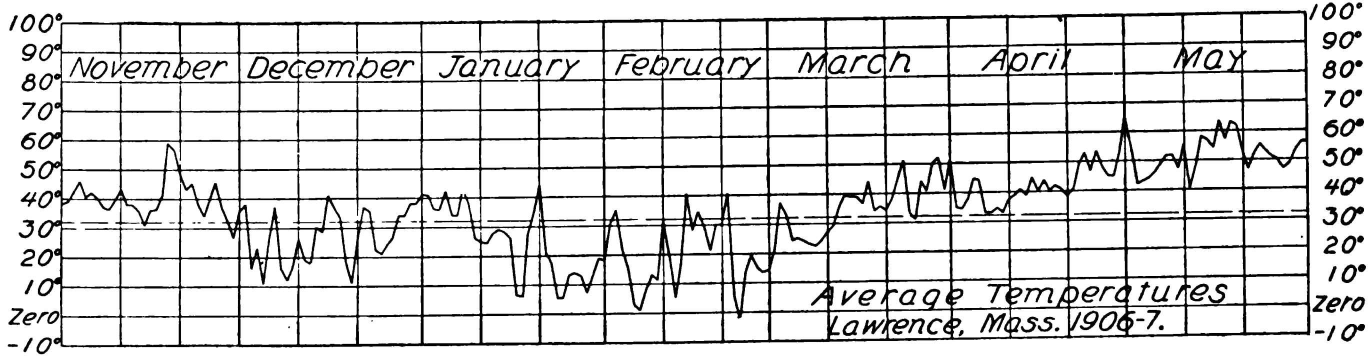

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
Zero
-10°
November
December
January
February
March
April
May
Average Temperatures
Lawrence, Mass. 1906-7.

FIG. 1.

1906, to June 1, 1907, has been prepared. It is seen that the temperature dropped below freezing the last of November, and there was scarcely any real thawing weather until well into March. At the time the last two bays of concrete were laid, December 17, the average temperature was just above freezing, but that night it dropped below freezing and the next day but one reached 6° above zero.

As soon as the concrete was laid in the arches, they were covered with straw to a depth of 6 inches, and later about 2½ feet of sand and gravel were placed on top of the straw, the last two arches being filled upon about two or three weeks after they were laid.

The contract requires, with reference to work in cold weather, General Clauses, Section 23:

" In case any unforeseen contingencies arise which will prevent the work being completed by November 15, 1906, and it becomes necessary to do work in the winter weather, no embankment shall be made and no concrete shall be mixed, nor placed, nor masonry laid, nor any other operation performed, likely to be interfered with by cold, during any of the months of December, January, February and March, and thereafter until the frost is out of the ground, unless permission be obtained from the engineer. If, however, the engineer is of the opinion that any operation can be satisfactorily performed during these months, he may give the contractor a special written permit, which permit shall define the work and the conditions under which such work may be done and such conditions shall be faithfully followed.

" The contractor shall be responsible for all defects in the work done during these months which may arise from the action of the elements, notwithstanding such permit and additional precautions taken. He shall make good such work, and shall make good any work destroyed or damaged by the frost, even though built at any other season of the year."

No permit had been given to the contractor to continue work in December.

A diagram of the easterly end of the filter where the collapse occurred is shown in Fig. 2. To the dotted line this represents a length of about 110 feet out of a total length of reservoir of 313 feet.

The general construction of the forms and the method of placing the concrete is shown in Plate I, Fig. 1. The only lateral bracing, it

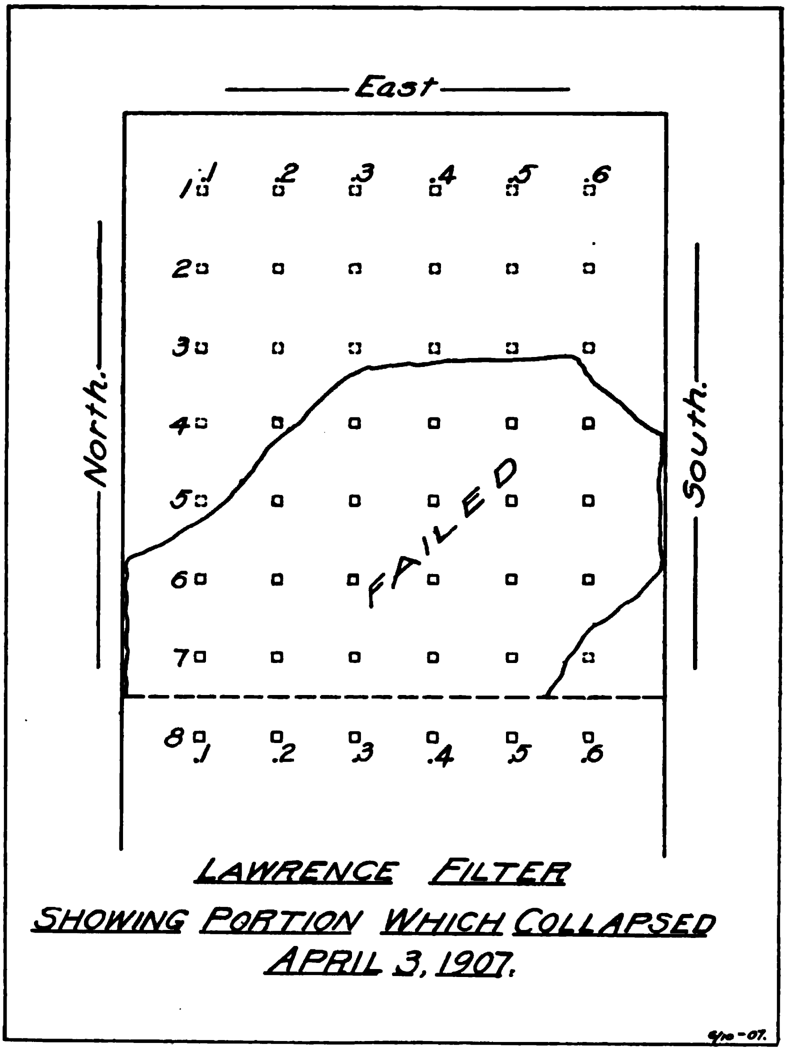


FIG. 2.

will be noticed, consisted of light wooden braces, nearly horizontal, resting against the piers at the height of the second clamp from the top. The only resistance to lateral thrust was therefore that due

FIG. 1. Forms for Roof of Lawrence Filter.

FIG. 2. After the Fall of the Roof.

to the weight of the pier and the adhesion of two short lengths of round rods in the bottom of the pier.

During the winter the centering had been removed from the first three bays of the roof, leaving a length of 4½ bays with the centering in place.

On the day previous to the fall the carpenters began to remove the centers from these last bays, so that at night all the centering was down except the half centers between the seventh and eighth rows of columns, the full centers in the next bay, and the four north arches between the fifth and sixth rows. The foreman carpenter told me that when he came on the next morning, April 3, he noted that a 4 × 8 inch horizontal piece in one of the half centers was twisted, but he did not attach any importance to it. The men began to work on the north arches of bay 5-6 when a cracking was heard, and they all got out from under. The break appeared to start about the center of the reservoir, — that is, about halfway between the two sides, — and the whole roof seemed to go down at once. Fortunately, the men were warned in time and no one was injured.

The visit of the writer to the filter was not until May 23, but the condition was substantially the same then as on April 3, the date of the fall, scarcely any clearing having been done.

The general condition of the reservoir a few hours after the fall of the roof is shown in Plate I, Fig. 2, and Plate II, Fig. 1. All the columns in the last row, line 8, against which the end of the centering was braced, were standing; but one of these columns at about the center of the reservoir and where the break was said to start is slightly canted. In the next or seventh row, four piers were standing, but all of them tipped, including the pier in the row under the southwest arch. The columns in the other rows were nearly all broken. Pier 8.3, which is shown as slightly canted at the time of the fall, was afterward pried over, and the cleavage of the base from the floor was smooth, as one would expect of a joint between concrete laid on two different days. The two steel dowels which projected into the pier had pulled out, leaving clean surfaces.

A view looking northeast after cleaning up the loose concrete and forms is given in Plate II, Fig. 2.

A closer view of the third row columns which were still standing showed that several of them were tipped toward the west, and a crack had opened at the top, that is, at the springing line of the arch, about ½ inch wide. Three were out of plumb from 1 to 2½ inches, and these were also cracked at the base as well as the top. In the portion of the roof remaining, cracks were noticed, mostly along the crown of the arch.

EXAMINATION OF THE CONCRETE.

The concrete at the time of the fall was so soft and crumbly that it could be readily pulled to pieces. At the time of my visit it was fairly hard, evidently having hardened very much since the failure. The stones, however, pulled from the concrete more easily than they should have done in first-class concrete, indicating that even at this time the concrete was not very strong. Concrete from the upper surface of the roof, especially in the thick masses above the columns, was noticeably weaker even at date of my visit than the concrete next to the centers. At the date of reading this paper, ten months after the accident, the samples referred to above are sound and hard.

EFFECT OF MANURE.

In certain places pieces from the top surface of the roof were much discolored. Examination showed that the concrete had been in contact with manure contained in the straw, while other neighboring portions of the roof surface which were covered with clean straw were of normal color. The discolored portions, the color extending to a depth of about 1 inch, were softer than the rest of the concrete and readily flaked when rubbed between the fingers. Although this did not extend deep enough to be in itself responsible for the failure of the roof, the condition was such as to show very conclusively that manure is a bad thing to place in contact with green concrete, and that when straw covering is employed, it should be free from manure.

In this connection the writer may say that he recently had occasion to examine a barn floor of concrete and also several concrete drains in this floor which had been in use for a number of years in continual contact with manure, and found the surface absolutely

FIG. 1. After the Fall of the Roof.

FIG. 2. After Most of the Debris had been Removed.

hard and perfect. A tank containing manure was also in similarly good condition. The conclusion, therefore, may be drawn that manure is likely to injure green concrete, while not affecting well made concrete after it has set and hardened.

SAND AND GRAVEL.

The sand and gravel used for the concrete were from a pile which had been excavated from the site of the filter. This material was screened into gravel for the coarse aggregate or ballast, and sand. Four samples of the sand were taken, and two samples of the screened gravel. Examination of the sand and of its analyses shows that it is all of medium quality, containing a somewhat excessive percentage of dirt for maximum strength, but none too much for water-tightness. Examination of the analyses of the gravel shows a large percentage of material under ¼ inch, the sample with the least fine material screening 20 per cent. below ¼ inch, although the contract specifies (Section 28), that, "all particles smaller than one quarter (¼) inch shall be screened out." The specifications require proportions 1: 3: 5. If 20 per cent. of the gravel is below ¼ inch, and therefore sand, the proportions are actually 1: 4: 4, thus giving a concrete greatly inferior in density and strength to that required by the specifications. Many of the gravel stones were covered with a coating of very fine clayey sand, which after drying in the laboratory and screening by hand for five minutes did not entirely come off. Tests by Mr. Howard A. Carson (recorded in the Seventh Annual Report of the Boston Transit Commission, 1901, p. 39) show one third greater strength for concrete made from washed gravel than similar concrete made with gravel coated with a thin film of dirt. The excess of fine material tends to make the concrete not only weaker but slower in setting and hardening.

The contract specifies (Section 28) that the gravel "shall be washed if necessary to render it sufficiently clean," but this was not done.

EFFECT OF LOW TEMPERATURE.

The temperature records taken at Lawrence during the winter of 1906 indicate only a very few days at which the temperature was above freezing.

As already stated, the last arches were not laid until December 17. On the following day, as shown by the curve in Fig. 1, the temperature dropped below freezing, and there were only a few days when the temperature was above freezing before the earth covering was placed. The covering naturally tended to equalize the temperature, so that the concrete would not then have the full benefit of the occasional warmer days during the winter and early spring.

It is common knowledge that continued cold prevents concrete from reaching its normal growth in strength. Tests at the Watertown Arsenal * and elsewhere, the results of which are readily available, have brought out this point clearly, showing that if the temperature is maintained below freezing the cement after several months has only a fraction, — on the average we may say about $\frac{1}{3}$, — the strength that it would have reached with a temperature of 70° F. Even a temperature as high as 39° F. retards the hardening so that the strength may not be more than two thirds of what would be attained at 70° F. As soon as any of the specimens were removed from the cold and placed in a warmer temperature the hardening was accelerated, and a strength nearly normal was soon reached.

At Lawrence the effect was similar, the concrete rapidly gaining strength after exposure to the warmer atmosphere in April and May.

CENTERING.

The contract specifies, Section 58:

"The contractor shall notify the engineers when he proposes to strike centers, but no centers shall be struck opposite the outside walls until the embankment has been completed to the springing line, and no other centers shall be struck until at least five (5) rows of vaulting beyond have been completed."

The five rows of centering which are required to remain in place at all times are evidently for the purpose of allowing the concrete to set and also to take up the thrust of the arches due to temperature or unequal loading. The contractor evidently assumed that

* Taylor & Thompson's "Concrete, Plain and Reinforced," p. 412.

the provision was only for the purpose of giving time for the concrete to set, for he was removing the forms with no diagonals left in place, except a few braces placed against a row of piers, which had only their own weight to keep them in an upright position.

Without attempting to analyze the thrust of the arches, it is evident that if the half center at the end had been loaded with earth to the full height, it would have balanced the pressure from the next arch, so that the line of thrust from all the arches would have come directly into the piers. However, in filling a roof like this, the earth cannot be carried square to the edge, but slopes off, probably in such a case as this at a slope of 1 to 2, or 1 to 3, so that there must be a thrust from the arches beyond it if they are unsupported.

The assumption that the thrust was a factor in the fall is strengthened by the facts that (1) one half of the bay between column rows 3 and 4 was laid as late as November 23, thus having only twelve days more to set with the temperature slightly above freezing than the outer bays, and yet this bay suffered the removal of the forms without apparent damage; (2) the bay between column rows 5 and 6, half of which was laid on the final date, December 17, 1906, did not fall on the day when the forms were removed from the first portion of it, although unreinforced concrete falls quickly with but slight warning; (3) warning of failure was given by cracking of the centers and apparently commenced in about the middle of the reservoir, near pier 8.3, which was tipped from the thrust of the diagonal braces against it.

CAUSES OF FAILURE.

The data presented enable us to reach definite conclusions in regard to the causes which contributed to the failure.

The design of the groined arch roof is one universally endorsed, being similar to that adopted with satisfaction in many other filters built from the year 1895 to the present time. It is consequently impossible to attribute the failure of the Lawrence filter roof in any way whatsoever to the design.

The causes of the failure therefore must lie in the construction. After removal of the forms supporting the roof the fall appears to

have been due to a combination of two causes, neither of which alone would probably have occasioned the accident.

(1) The thrust of the arches.

(2) The weak condition of the concrete because of

(*a*) Low temperature, which retarded the hardening;

(*b*) Improper screening of gravel, producing an excess of sand which tends to make concrete slow in hardening;

(*c*) Dirty gravel, reducing the strength of the concrete.

All of these causes were probably contributory to the fall. The subsequent hardening of the concrete indicates that no trouble could have ensued if the forms had remained for a longer time and until more arches had been placed.

REPAIRS.

The wrecked portion of the roof and the broken piers were removed, and replaced by a new structure built to the same design. The arches which remained standing, but which were cracked and had separated along the crown, and the piers supporting them, which were slightly tipped, were thrown back into place by jacking up the arches vertically, and at the same time jacking them horizontally to bring them into place, close the cracks, and plumb the piers.

PRODUCER GAS PLANTS.

BY HENRY CROWTHER,* PHILADELPHIA, PA.

[*A discussion on paper by Harry L. Thomas, read January 8, 1908.*]

We have installed gas-producer plants up to 800 and 1 000 horsepower. We are doing more of this in the West than in New England. We have installed for the American Locomotive Works, at their Richmond shops, a 500 horse-power gas-producer plant which is developing 160 000 000 foot-pounds per 100 pounds of coal. For the Pennsylvania Railroad, near Wilmington, we have installed two 100 horse-power gas-producer plants driving 100 horse-power Westinghouse engines. At Poughkeepsie, N. Y., and at New Orleans, we have installations of gas-producer plants. The duty developed has ranged from 120 to 140 and 160 million per 100 pounds of coal.

Mr. Thomas hit the nail on the head when he said, in summing up, that, after all, experience is necessary in running these plants. This is no trick after a man has had some experience, but it is impossible to expect a steam engineer, or a steam boiler fireman, to take hold of one of these plants and run it offhand. There are certain precautions to be observed, the principal of which are, — that your coal should be of as uniform a character as possible, and it should not exceed a certain per cent. of hydrogen, say about 18 to 20 per cent., because if you exceed that you get back firing. This was the cause of Mr. Thomas' trouble; he struck there a coal with a high per cent. of sulphur, which, if persisted with, would have pitted the engine so badly in the course of a few weeks that he would have had to renew the parts. These are points which come with practical experience.

The economies of producer gas plants are so manifest that, in the West particularly, where they seem to have taken these things up more extensively, they are being rapidly adopted, and up to large units. We haven't put in anything over 1 000 or 1 200

* With R. D. Wood & Co.

horse-power yet, but they are building now for the United States Steel Corporation gas engines up to 4 000 horse-power; they operate either on natural gas or blast-furnace gas, but they could be operated on producer-gas with by-product recovery. This, however, is only possible in large units, 3 000 or 4 000 horse-power and upwards. The whole thing sums itself up when you can show an economy of from three to five times what a steam engine will give you. When you can develop, as has been done, 20 horse-power for one cent an hour per horse-power, with coal at $1.50 a ton, the fact is forced upon you that the gas-producer with the gas engine is going to be, and is already, a very active competitor of the steam engine, and is bound ultimately to force it out.

The chief engineer of the Pennsylvania Railroad told me last year that in the opinion of their engineering department the steam turbine was only an intermediate step between the steam engine and the gas engine. It must be remembered, if you please, that steam boiler men and steam engineers are a development of a century of progress, and they know these things by rote. If you will give the same amount of attention to the operation of your gas engine and gas-producer as you have given to your steam engine and steam boiler, there will be no difficulty in their operation. And while, as one gentleman very aptly said, we had better bear the ills we have rather than flee to those we know not of, yet, at the same time, those latter ills are more apparent than real, if you get right down to it.

In Poughkeepsie the saving effected by the gas-producer plant over the old steam plant paid for the cost of the plant (about $4 000) inside of twenty-two months. They saved at the rate of about $185 or $200 per month, in comparison with what they had been paying before with a steam engine and steam boiler.

THE PRESIDENT. I should like to ask Mr. Crowther what is really the best type of fuel to use in these plants.

MR. CROWTHER. Anthracite coal, undoubtedly. Anthracite gives you a clean gas; the B.t.u. runs about 140, and you have no trouble with cleaning.

The report of the United States Geological Survey, which can be had from the government, shows that at the government testing

station at Forest Park, St. Louis, they tested out lignite, peat, wood, straw, coke, charcoal, — everything, in fact, that could be burned, — and yet they got back to the fact that anthracite coal is the best fuel for all purposes. But bituminous coal (if you don't get it too slack), or even run of mine, with automatic cleaners, is all right, although in that case, when you have to put tar cleaners in, it involves additional cost, of course. Therefore anthracite remains the best. In other words, the best fuel is that which is free from the hydrocarbons — a high percentage of hydrocarbons.

Mr. Thomas. Mr. President, if I may be excused for speaking about one other thing which is brought to my attention, which I omitted in the paper, the matter of feeding the generator: perhaps you all understood clearly how our generator is fed, — we clean the fire and fill the generator once in three hours. Under good practice that is as often as it is necessary to do it. Sometimes, if the coal is running rather poor, we have to clean it every two hours and a half, but we usually clean it every three hours. And whereas we were advised in the first place to sift the ashes and put them back, our experience has taught us there is no economy in doing that, for while it may cut down the record of the coal for a day's run, it will make so much ash and dirt in the fire that the additional coal used the next day will make up what you did not use that day. So we simply take that and put it on one side, and we contemplate shaking it out and burning it under our steam plant to get rid of it.

Mr. Crowther. With proper handling a gas-producer can be started with the engine in about an hour to an hour and a half, and when the fire has been simply let stand it only requires a few minutes over night.

At our works at Camden we have gas-producers coupled to different makes of engines, and our men, naturally having had much experience, have no difficulty in starting promptly. If it took a day to start a fire in order to get gas from a producer to an engine, the company making them had better go out of business. The statement quoted by Mr. Thomas is far-fetched, and the man who made it did not understand his business. That is the only charitable remark that can be made about that.

Mr. Farnum. Mr. President, I would like to ask how many

men it takes to run this plant, and if there is any economy in that direction.

MR. THOMAS. In the matter of attendants, our plant is exactly the same as the steam plant, — one man takes care of the plant at both places; it takes but one man.

MR. CASSELL. I would like to inquire if either of the gentlemen can give us the relative cost as between the establishment of a steam plant and this gas plant they are talking about, in an approximate manner.

MR. CROWTHER. Yes. The cost of a gas-producer plant, fully equipped with producer, gas engine, washers, scrubbers, and everything of that sort, as compared with a steam plant, is very nearly a stand-off. There are probably two or three dollars more you might figure on per horse-power, but the increased cost of the gas engine is more than offset by the increased cost of the boiler house, stack, foundations, and that sort of thing, as compared with a gas-producer house. I am speaking of the ordinary sizes, built of corrugated iron, or something like that.

While the cost of the installation of the gas-producer is probably 2 or 3 per cent. more than that of a steam plant, perhaps the cost of maintenance and repairs, on the other hand, is largely in favor of the gas-producer.

Speaking on that very point which Mr. Thomas cited, of getting a gas-producer started, the Erie Railroad at Jersey City has had now for nine years, I think, Westinghouse gas engines running with R. D. Wood producers, and in one of those producers for nine years the fire has never been out; it has never, therefore, required relining with fire brick. So that you can very readily understand the great economy of the maintenance and repair charges. But, roughly, it is about a stand-off; there is very little difference, in large installations.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 11, 1908.

President Alfred E. Martin in the chair.

The following members and guests were present:

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, A. F. Ballou, G. W. Batchelder, F. E. Bisbee, George Bowers, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, C. E. Childs, J. H. Child, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, C. E. Davis, A. W. Dean, M. J. Doyle, E. D. Eldredge, B. R. Felton, A. N. French, C. W. Gilbert, A. S. Glover, F. W. Gow, F. H. Gunther, E. L. Grimes, F. E. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., B. B. Hodgman, H. G. Holden, J. W. Kay, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, J. J. Kirkpatrick, E. E. Lochridge, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, H. A. Miller, William Naylor, F. L. Northrop, O. E. Parks, H. W. Sanderson, P. R. Sanders, E. M. Shedd, G. H. Snell, G. A. Soper, G. A. Stacy, W. F. Sullivan, R. J. Thomas, W. H. Thomas, D. N. Tower, W. H. Vaughn, C. K. Walker, F. B. Wilkins, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall. — 65.

Honorary Member.

Wm. T. Sedgwick. — 1.

Associates.

Allen & Reed, Inc., by Henry W. Littlefield; Anderson Coupling Company, by F. A. Leavitt; Ashton Valve Company, by C. W. Houghton and Charles L. Bucknam; The Fairbanks Company, by F. E. Smith; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; International Steam Pump Company, by Samuel Harrison; Jenkins Bros., by H. F. Fiske; Charles Millar & Son Company, by Charles F. Glavin; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin and J. G. Lufkin; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by F. L. Northrop; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown;

A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. M. Barnard; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by W. F. Woodburn. — 29.

GUESTS.

F. W. Dinwiddie, Gardner, Mass.; George F. Merrill, superintendent water works, Greenfield, Mass.; Charles N. Oakes, Westfield, Mass.; James G. Hill, Lowell, Mass.; John F. Stark, president Pennichuck Water Works, Nashua, N. H.; W. W. Trowbridge, West Newton, Mass.; L. H. Cornfel and W. Burmbain, Boston; Charles F. Chase, Providence, R. I.; William E. Smith and Lettice R. Washburn, New Bedford, Mass.; A. E. Blackmer, Plymouth, Mass.; Thomas G. O'Connell, Wakefield, Mass. — 13.

[Names counted twice — 6.]

The Secretary read the following names of applicants for active membership:

Arthur E. Blackmer, Plymouth, Mass., superintendent of Water Works; George F. Merrill, Greenfield, Mass., superintendent of Water Works; William E. Smith, New Bedford, Mass., member of Water Board; William H. Pitman, New Bedford, Mass., member of Water Board; Lettice R. Washburn, New Bedford, Mass., member of Water Board.

On motion of Mr. Eglee, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants whose names had been read, and he having done so, they were declared elected members.

The Secretary read the following communication:

PHILADELPHIA, February 19, 1908.

NEW ENGLAND WATER WORKS ASSOCIATION,
715 Tremont Temple, Boston, Mass.:

Gentlemen,— Believing that the salvation of the remnant of our forests is one of the most pressing duties of the nation, I respectfully urge your careful and favorable consideration of House Bill No. 10 457, "For Acquiring National Forests in the Southern Appalachian Mountains and White Mountains," and the adoption at an early meeting of resolutions urging this matter upon the Committee of Agriculture, Hon. Charles F. Scott, chairman, Washington, D. C.

Yours truly,
JOHN C. TRAUTWINE, JR.

THE PRESIDENT. The communication has been before the Executive Committee and has been referred to this meeting by action of the committee. I think Mr. Baker has something to say on the subject.

MR. M. N. BAKER. When this matter was brought up in the Executive Committee there was some discussion on the broader subject of the conservation of the natural resources of the country, which subject includes not only the preservation of forests, but the conservation and the development and utilization of the water resources of the country, and also a study of such other natural resources as our coal supplies. As probably all those here know, there was appointed some months ago by President Roosevelt a commission styled "The Inland Water-Ways Commission," to take up, primarily, an investigation of and to map out a scheme for the development of the navigation of the country; but the President very wisely made his instructions to this commission broader, and the commission in its recent report, in accordance with the detailed request of the President, entered upon a consideration of the broad questions of the conservation of the natural resources of the country, giving particular attention to the water resources.

It is unnecessary to elaborate upon this point, but I wish to bring to your attention the fact that the national engineering societies have taken up this matter of the conservation of the natural resources of the country, and that also there is to be held in May, at the call of President Roosevelt, a convention of the governors of all the states of the Union at Washington just about the time of the meeting of the American Water Works Association. And at this conference of the governors with the President there will be a number of papers read, and discussions, and perhaps the formulation of some policy in regard to the conservation and future development of the natural resources of the country.

Now as water-works men and as engineers, the members of this Association are, of course, primarily interested in all that pertains to the water resources of the country, their conservation in quantity and in purity. The bearing of the forestry question upon the water resources of the country is so evident to all that nothing

need be said upon that subject. The Executive Committee of this Association decided to recommend to the Association the appointment of a committee on the conservation and development and utilization of the natural water resources of the country, that committee to consist of five members, appointed by the chair, and to have power to confer with and to coöperate with like committees from the engineering societies or any other associations that might take similar action. Inasmuch as we have a very full program for this afternoon, I will not take up any more of your time, but I think it is evident to all that it is very important that this Association get in line with others and appoint a committee to take this matter into consideration and to coöperate with others.

I might say just one thing more, which will be of particular interest to the members of this body who are not informed of the fact, and that is that there is now under consideration by the United States Geological Survey and by the United States Bureau of the Census, a census of the water-powers of the United States. Such a census, you will remember, was taken in 1880, but it has not been revised since that time, and meanwhile there have been very great developments and very many changes, and it is possible, although not certain, that another census of the water-power will be taken. It will be becoming for this Association, and for its individual members, to do what can be done to further the taking of such a census.

MR. SULLIVAN. I move that the report of the Executive Committee be accepted and adopted, and that a committee of five members be appointed by the President to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country.

The motion was adopted, and the President subsequently appointed the following-named gentlemen as the committee: M. N. Baker, William T. Sedgwick, Leonard Metcalf, Allen Hazen, and George A. Soper.

MR. EGLEE. Would it not seem desirable, Mr. President, that an expression of opinion from this Association should be made at the present time and forwarded as requested? Every one here

is certainly interested in the preservation of the water-power and in the conservation of water supplies, and it would seem as though a resolution passed here, or framed by the committee to be passed before the close of this session, might be of value. The appointment of a committee of five to follow this legislation is, of course, a very good thing, but, as I understand it, we do not meet again until June, which will be after the adjournment of Congress. I would make the suggestion, not as a motion, that a committee of two might be appointed at the present time to draft a resolution, which might possibly be endorsed by this session of the Association, and forwarded to the proper official.

MR. SULLIVAN. This matter came up in the Executive Committee about half past twelve to-day, and after talking it over we thought the time was too short in which to draft any resolutions, and it was the intention of the Executive Committee to have this sub-committee appointed who would take care of that matter.

MR. EGLEE. Would Mr. Sullivan permit an amendment to his motion to the effect that the committee appointed by the President should be empowered to draft a suitable resolution and forward it to the proper officers previous to the adjournment of the present session of Congress?

MR. SULLIVAN. I certainly would accept that as another motion, but my motion has already gone through.

THE PRESIDENT. I understand Mr. Eglee makes this as a suggestion, but I will put it as a motion, that the committee be instructed to prepare such a resolution.

The motion was adopted, and the President announced the committee would govern itself accordingly.

The first paper of the afternoon was read by George A. Soper, Ph.D., consulting sanitary engineer, New York, on "The Typhoid Fever Epidemic at Watertown, N. Y., in 1904." The paper was discussed by Prof. William T. Sedgwick and Prof. C.-E. A. Winslow.

Mr. E. L. Grimes, chief engineer, Bureau of Water Supply, Troy, N. Y., gave a description of the "Troy Water Works Extension."

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, March 11, 1908, at 11.30 A.M.

Present: President Alfred E. Martin, and George A. Stacy, M. N. Baker, Robert J. Thomas, George W. Batchelder, D. N. Tower, George A. King, Michael F. Collins, William F. Sullivan, and Willard Kent.

Five applications were received and recommended for membership, viz.:

William H. Pitman, member Water Board, New Bedford, Mass.; William E. Smith, member Water Board, New Bedford, Mass.; Lettice R. Washburn, member Water Board, New Bedford, Mass.; Arthur E. Blackmer, superintendent Water Works, Plymouth, Mass.; George F. Merrill, superintendent Water Works, Greenfield, Mass.

Messrs. George A. King and D. N. Tower, members of the Committee on the June Outing, presented a detailed report (appended hereto) of the proposed arrangements for same, and on motion of Mr. M. N. Baker the report was accepted and the committee continued. The same committee was by vote authorized to procure a photograph of surviving charter members of the Association on the occasion of the June meeting.

The report of Editor Sherman with reference to a revision of the prices charged for back numbers of the JOURNAL of the Association wasreceived, accepted, and, on motion of Mr. M. F. Collins, it was voted that the recommendations of Mr. Sherman be adopted and that the prices named in his report be and hereby are established. This report is appended to these minutes.

A communication from Mr. J. C. Trautwine, Jr., with reference to forest reserves was received, and, after discussion, on motion of Mr. George A. Stacy, it was voted that the Executive Committee recommend to the Association the appointment of a committee to represent this Association in behalf of the movement to con-

serve the natural resources of the country. Mr. M. N. Baker was delegated to present the subject to the Association.

The subject of the September convention was discussed, but no action taken.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

REPORT OF SUB-COMMITTEE ON JUNE OUTING, 1908.

TAUNTON, MASS., February 29, 1908.

The sub-committee on the proposed outing to Plymouth presents the following report:

The boat from Boston to Plymouth will begin making its daily trips on Wednesday, June 17, and the boat is always crowded on that date. The schedule time for leaving Boston is 10 A.M., and reaching Plymouth at 12.45 P.M.; on returning, leave Plymouth at 3.30 P.M., and reach Boston at 6.15 P.M. The regular fare is $1.00 round trip and 75 cents one way. The management would give us a special rate of 75 cents round trip and 50 cents one way. A lunch counter is provided on boat, and undoubtedly some provision could be made for a luncheon for the whole party.

The New York, New Haven & Hartford Railroad now have a train leaving Boston at 8.43 A.M., via Cohasset, and due at Plymouth at 10.45 A.M., and one leaving Plymouth for Boston via Whitman at 5.56 P.M., and due in Boston at 7.17. Undoubtedly there will be trains at about these hours in June and probably more trains than are now scheduled. A party of one hundred and fifty could be carried in two special coaches on regular trains, but if numbers are considerably in excess of one hundred and fifty, a special train would be necessary.

The one-way fare is 75 cents, but for parties traveling together on specified train the following round-trip prices are made:

50–74	$1.20
75–99	1.13
100–149	1.05
150–199	.98
200	.90

Mr. Blackmer advises dining at Hotel Pilgrim, which is about three miles east of the town at the "Head of the Beach." Dinners could be served at prices running from 75 cents to $1.50 per plate, the price to include electric car ride in special cars from the center of the town. The hotel will probably not open before the middle of June.

Single admission to Pilgrim Hall is 25 cents; in lots of one hundred, 10 cents each, but the one hundred must actually go into the hall. A price of 20 cents each for seventy-five has been made occasionally and could probably be obtained if desired.

The committee visited Plymouth and conferred with Mr. Blackmer, the superintendent of the water works, and in view of his desires and the information given above, we make the following

RECOMMENDATIONS:

That the Association make an all-rail trip to Plymouth on the fourth Wednesday of June (the 24th), leaving Boston at about 8.43 A.M., and going by way of Cohasset, and returning by way of Whitman at about 5.56, to reach Boston about 7.17.

That on the arrival in Plymouth it assemble at the Armory, which is about three minutes' walk from the railroad station, to receive a welcome to the town.

That at about 11 o'clock opportunity be given to visit the following places: Pilgrim Hall, nearly across the street from the Armory; the water-works shop on Howland Street, about three minutes' walk from the Armory, where 18-inch cement pipe will be in process of manufacture; the Rock, monument, and such other places as members may desire to visit; that at 12.45 special electric cars be taken at the Armory for the ride to Hotel Pilgrim for dinner; that on the return from the beach those who desire take the barges, provided by the town authorities, at Town Square and visit the work of laying the 18-inch cement main which is to be laid between Little South Pond, the source of supply, and the pumping station. This work will probably be in progress about two miles south of the town; members who desire to make this trip to notify Secretary before leaving Armory in morning.

There are always plenty of carriages to be hired for 25 cents per passenger for visiting different points of interest in town.

The cost of the trip should not exceed $2.25, based on an attendance of one hundred.

We base our estimate on the following figures:

Railroad fare...........	$1.05
Dinner.................	1.00
Admission Pilgrim Hall,	.10
Printing, tickets, etc....	.10
	$2.25

Respectfully submitted,

(Signed) GEORGE A. KING,
D. N. TOWER,
Sub-Committee.

Report of the Editor on Prices for Back Numbers of the "Journal."

Boston, February 26, 1908.

Mr. A. E. Martin,
President N. E. Water Works Association,
Springfield, Mass.:

My dear Mr. Martin, — In accordance with the understanding at the last meeting of the Executive Committee when we discussed the matter of price of back numbers of the Journal, I send you the following memorandum and recommendation for presentation at the March meeting, since, unfortunately, I shall be in the West at that time and unable to attend the meeting.

Some years ago we established, by vote of the Executive Committee, a series of premium prices on back numbers of the Journal, by which the price of each copy was increased by 15 cents for each year previous to a certain date. This, of course, makes some of the old numbers very high priced, although, as a matter of fact, we have as many of some of the earlier numbers on hand as we have of some of the comparatively recent ones. A couple of years ago it became necessary to give away quite a number of surplus copies of the Journal in order to clear our shelves. At that time, however, we took pains to retain at least twenty-five copies of all the issues of which we had as many as twenty-five to start with.

We now have on hand five or less copies of only four issues, viz.: No. 4, Volume 1, of which the present price is $2.85; No. 2, Volume 2, the price of which is $2.70; No. 4 of Volume 10, price $1.50; No. 4 of Volume 11, price $1.35. On the present schedule of prices the price of a complete set of the Journal to 1907, inclusive, is $125.50.

I now feel that the effect of the present schedule of prices is, to a large extent, to prevent sales, and as each new issue of the Journal makes an addition to our stock and requires additional storage room, I am inclined to feel that it would be wise to fix a price at which we could move the old issues more rapidly. I also feel that we should fix a price for a whole set at which we could more easily place them in public libraries or libraries of scientific schools.

There have been up to date twenty-one complete volumes of the Journal and two issues of Transactions, or twenty-three annual volumes, one of which covers a year and a half and contains six numbers of the Journal (Volume 15).

I recommend that for all sales of an entire set or of early volumes of the Journal required to make up a set for libraries or for individuals, we make a price of $3.00 per volume (except for Volume

15, which contains six numbers, and for which the price should be $4.50), making $70.50 for a full set up to and including 1907; that for single copies of the JOURNAL of which we have more than five copies on hand the price be $1.00 each, and where we have five or less copies, the price be $2.00, irrespective of the date of issue. Also that where we have not more than five copies of an issue on hand, complete volumes containing the issue be sold only by the single number *except* in case of selling a more or less complete set at one time.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor*.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXII. September, 1908. No 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE SUB-AQUEOUS PIPE AND ELECTRIC CABLE WAY AT GLOUCESTER, MASS.

BY HERMAN W. SPOONER, CIVIL ENGINEER, GLOUCESTER, MASS.

[*Read September 18, 1908.*]

Gloucester is a city by the sea, situated, with the exception of one ward, upon an island between Massachusetts and Ipswich bays, being bounded by them, together with the Squam River and canal. Of course you have heard it said that Gloucester is a part of and located upon "Cape Ann." This section of Massachusetts was a cape, years ago, before it was cut off from the mainland by the construction of the canal, that the skippers of the fishing fleet might lay a more direct course to the Grand Banks. Hence, after the canal was opened connecting the river and harbor, the cape became an island, upon which there was no opportunity to procure a supply of water sufficient to meet the steadily increasing demand.

It will be readily understood that the water mains, — the leading supply mains, — must pass under the water of canal or river at a sufficient depth below low water to cause no interference to navigation. When the plant was built, in 1884, the single supply main was laid just below the bottom of the canal, and it served its purpose until it became advisable to dredge and widen to accommodate craft at all tides, as the bed of the old canal was at the level of low-water mark, allowing no navigation even for small boats during periods of low tide.

On account of this change in width and depth, it became necessary to lower the gas and water mains to a depth of at least 19 feet below high-water mark.

Because of the nature of the ground in the vicinity of the canal, the close proximity to the only avenue by which entrance is gained to the city proper, and the waters of the harbor, it was decided that an attempt to dredge or open cut a trench to the required depth and lay twin mains therein was inadvisable. Therefore a location for vertical shafts and a connecting horizontal tunnel was considered, it being desired to avoid such locations as would cause damage to land owners, hindrance to public travel along Western Avenue, and excessive construction cost. It was decided, therefore, to make borings along a proposed line of construction southerly from Western Avenue, and wholly within lands owned and controlled by the city.

The Harbor and Land Commissioners decided that all pipes or mains should be placed at such a depth below low-water mark as to afford ample opportunity to dredge to a depth of at least 10 feet below this mark, of which only about 6 feet is to be attempted at present.

The test wells or borings were made to a depth of 50 feet below the surface of the floor of the present bridge, and in several instances about 50 feet below the bed of the canal, which is practically equal in level with low-water mark; samples of the materials encountered were procured at different levels, most of which indicated coarse gravel, sand and boulders, but no clay. As borings made north of the bridge for the Harbor and Land Commissioners indicated similar materials, and as it was evident that no clay in any amount was to be found, the final location was established on the southerly side of the avenue within the park. In 1904 plans were prepared, approved by the Water Board and the Harbor and Land Commissioners, including an alternate design, the latter being radically different from the first in all parts, and requiring the pneumatic method of construction throughout. A pamphlet covering " Notice to and Information for Bidders, Bid, Contract, Specifications and Bond " was prepared by the writer, examined and approved by the Board and the city solicitor, and forwarded to such parties as applied.

The bids were advertised in the local and contracting papers, and copies of the pamphlet delivered to fourteen applicants, eight of whom called to examine the plans and view the vicinity of the

proposed work. The samples of the materials taken from the test wells or borings were exhibited and the plans examined, and nearly all applicants decided from the location and nature of the ground through which the work was to be constructed that they would not care to bid.

One bid to do the work was filled out in the required form and filed, together with the required deposit, by Charles R. Gow and John E. Palmer, operating under the firm name of Gow & Palmer, of Boston, Mass.

The bid covering the alternate design, which will be described hereinafter, was considered by the Water Board at length. This bid covered the construction of the entire work, the price named being two hundred and fifteen dollars ($215) per horizontal linear foot for a tunnel to measure, when completed, 130 feet between the centers of the vertical shafts.

The contract and plans required that the contractors construct two circular vertical masonry shafts, interior diameter 11 feet, one on either side of the canal, surrounded to within a few feet of the surface by steel cylinders. The methods of construction were left to the discretion of the contractor, unless objection was made thereto by the writer, and it was assumed that the constructors would place the cylinders in position in a timbered square-sheathed excavation, line them with masonry of the required thickness, and then excavate from the interior, allowing the lined cylinders to settle. A tunnel 9 feet in interior diameter, having a brick wall 1 foot in thickness and incased within a cylinder consisting of steel plates, was to be constructed between these vertical shafts. After the construction of the shafts and tunnel, the contractor was required to place or imbed in concrete in the bottom of the tunnel six lines of vitrified six multiple duct extending along the entire length of the bottom of the tunnel; two lines of cast-iron pipe 20 inches in interior diameter were to be placed above the concrete in which the ducts were to be imbedded, together with a 12-inch main to convey illuminating gas, all of which were to be supported upon brick piers and extended upward through the shafts to a point about 4½ feet below the natural surface. The vertical shafts were to be divided by brick walls 8 inches in thickness into three compartments, the larger portion to be utilized

for the water and gas mains, the other part to be subdivided into two parts or quarters to accommodate high and low-tension wires or cables; both shafts were to be covered with concrete floors, entrance to be made through cast-iron manholes. After considering the bid at length, it was decided to modify the plans that the cost might be reduced, and ring timber or a cylinder of pine 6 inches in thickness to take the place of the steel plates surrounding the brick walls of the tunnel was proposed by the party presenting the bid. This alteration in the original cross-section was drafted by the writer, submitted to the bidder for consideration, and in reply a bid of twenty-six thousand dollars ($26 000) was received to complete the work in accordance with the revised plans and specifications, equivalent to two hundred dollars ($200) per horizontal linear foot.

The Water Board then awarded the contract to Messrs. Gow & Palmer. The first excavation in connection with the actual performance of the contract was made on April 4, 1905, in Marine Park, at the site of the easterly shaft. The steel cylinders, 13 feet in diameter and more than 12 feet high, together with a shorter section of special construction for use as a shoe or bottom piece, arrived by lighter on April 15 and were landed in the park, together with a hoisting engine, derrick, pumps, and other apparatus.

A circular excavation was made for the shaft, sheathed with matched plank 2 inches in thickness, the sheathing being supported by rings of 4-inch channel iron, leaving an opening in the clear of 13 feet 9 inches in which to operate. At a depth of 10 feet boulders were encountered in the coarse gravel, which were removed after blasting; water immediately began to enter the excavation in small volume and was removed by a 3-inch pulsometer pump.

At a depth of 18 feet a decided change was noted in the material, fine dead sand being found, and a decided increase in the quantity of water was evident.

On April 14, when a depth of 19 feet had been reached, the shoe-piece of the cylinder, having a special reinforced cutting edge upon which the masonry lining wall was to be constructed, was placed in position within the sheathing, and a second section of the cylinder was then adjusted, the eye (or portion which was to

be cut out later when the shaft was completely lowered, and through which the tunnel was to be started) centered, and preparation made to place the concrete lining. Fine screened sand was placed between the sheathing and the cylinder to fill the void and act as a guide, which later appeared to be an error, causing great loss of time and expense to the contractor.

While the sheathing was being placed for use as a form to support the concrete lining of the easterly shaft, an excavation was commenced on the westerly side of the canal at the site of the west shaft, in which many large boulders were found and removed after blasting, and from which the cables of the Postal Telegraph Company were removed. This opening was made in the same manner as the easterly excavation; the materials encountered at the several levels were almost identical with those found upon the east side of the canal.

The interior of the cylinder in the east shaft was treated with a three-ply coating of waterproofing, the steel receiving a coat of tar, and tarred paper being applied thereto, and this operation was continued until the desired amount had been placed.

Forms of dressed $1\frac{3}{8}$-inch plank were erected, supported within by rings of double angle-iron, allowing for the placing of concrete 1 foot in thickness inside the waterproofed cylinders. The following mixture of concrete was required and placed: To each 380 pounds of dry Portland cement there was added 5 cubic feet of fine and 11 cubic feet of coarse crushed stone, and 4 cubic feet of clean, sharp bank sand, the whole being mixed very wet.

All concrete, and all mortar used in brickwork, was mixed by hand and made with Atlas Portland cement, which passed all of the required tests which are given hereunder.

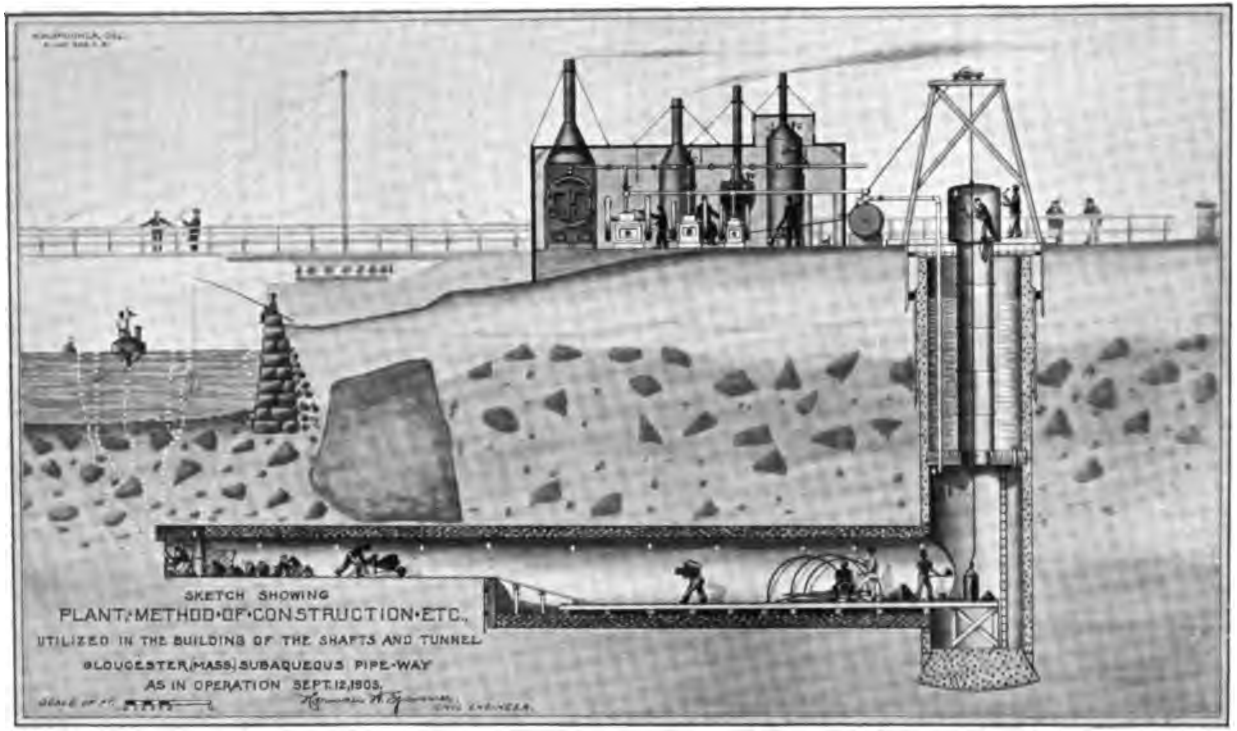
The double angle-iron rings supporting the forms were set 3 feet apart and were replaced by wooden block rings after the concrete had attained a sufficient degree of hardness. Hooked bolts were set in the concrete as the lining walls were erected, to which stagings may be attached inside the cable chambers.

When several vertical feet of the concrete lining walls had been placed, it was noted that the entire cylinder had settled about 6 inches into the gravel, the cutting edge resting upon a boulder which was found to be under the easterly edge. After this boulder

had been partially removed by blasting, the structure again settled about 3 inches. It was found that the boulder was of large size, and after continued small blasts, small amounts of powder being used on account of the close proximity of the cutting edge, the cylinder slipped past this obstruction and reached a depth of about 21 feet by easy stages.

At this time (April 24) the structure was going downward at the rate of about 20 inches in eleven hours and was becoming gradually out of plumb. The lowest portion of the edge was then blocked and the high side weighted with all available material, but no progress was made, the cylinder having a decided tendency to remain stationary. Another section of steel cylinder was attached to the loaded walls and lined with concrete, the structure being at this time about 6 inches out of level in the width. In this position the cylinder continued to settle slowly notwithstanding the efforts made to guide it to a level or plumb position. It was noted that the fine screened sand which had been placed between the sheathing and the cylinder shifted continually, causing the movable structure to be jammed far to one side, and on account of the shape of the excavation (round) and the impossibility of moving the sand guide at will, the space being too small, it was found to be impracticable to right the cylinder. The volume of water entering the excavation rapidly increased, and as the tide turned, the laborers were obliged to leave the bottom on account of the absence of pumps of sufficient capacity. At this time two 3-inch pulsometer pumps, assisted by a large single-cylinder Emerson pump, were in continuous operation, the depth of the excavation being about 25 feet below the surface of the park and about 5 feet below the low-water mark in Gloucester harbor. It was the intention of the contractor to complete the work without the use of compressed air, treating the ground through which the work was to be built with cement grout, this method being less expensive and having been used to advantage in other and similar work. Here, however, it was found that the nature of the gravel was such that the ground waters at all times moved freely through the ground, so that there was no opportunity at any time to leave grout in place for a sufficient period to allow of its attaining the initial set. Therefore, on May 2, the contractor decided to resort

PLATE I.



PLANT AND METHOD OF CONSTRUCTION.

to the use of the pneumatic method of construction. At this time the bottom or cutting edge of the cylinder was about 7 feet below low-water mark, it being necessary to lower the structure about 20 feet further before the required depth was reached. During the next two days the cylinder was worried down to a bed consisting of very coarse, hard gravel and isolated boulders to a depth of 28 feet below the surface of the park.

A recess was cut in the concrete lining to receive the wooden deck which was to support the compressed air tube and lock, and work in the east shaft was abandoned until the apparatus, air compressor, additional boilers, receivers, etc., could be assembled.

The cylinders to be placed within the excavation on the west side of the canal were rolled across the drawbridge and placed in correct order inside the sheathing with the aid of shears, power being furnished from the plant on the east side of the canal. Before being placed in position, six skids or guides consisting of timber 4 by 6 inches in size were affixed by lag screws to the sheathing, being notched at each ring of channel-iron, this pattern of a guide being used in place of the screened sand used in the east shaft. The inside of this cylinder was treated in the same manner as was the one in the opposite shaft and the walls constructed of concrete, an air deck, 18 inches in thickness, being built into the walls as the work progressed. The materials encountered in excavating were nearly identical with those found in the east side except that strata of gravel mixed with iron through which the water entered freely were passed through.

The pumping apparatus was moved to the west shaft and an attempt made to work this cylinder to a greater depth than was reached in the east shaft, but when a level had been reached which was within a fraction of an inch of the level of the bottom of the first shaft, the contractor was forced to abandon operations and wait for the application of compressed air.

While work was being carried forward on the westerly side of the canal, a small compresser with a receiver had been installed near the derrick on the east side of the canal, and on May 27 the air-lock and tubing especially designed and built for this work arrived and were ready, together with the head-house, and in operation, four days thereafter. Previous to this time there had

been very little continuous work, and as when using the pneumatic method there is a continuous expense to maintain a dry excavation, two shifts were organized. The day shift was in charge of the foreman, Mr. Charles B. Lewis, the other, or night shift, being placed in charge of Mr. Russell. Each shift worked eleven hours and consisted of foreman, stationary engineer, fireman, locktenders, miners, tenders, and muckers, generally eleven men being employed during each shift. The men employed upon this work were of the first rank in their several vocations, exercising great care in the performance of the duties assigned to them, and on this account, if for no other reason, the writer is pleased to be able to state that there were no men injured during the execution of this contract, and the final result is entirely satisfactory.

The air compressor was in operation thereafter continually until the work was nearly completed. All materials were removed, and all materials required in construction were transferred, through the air-lock, thus increasing the cost of construction nearly fourfold.

The cylinder was bound in such a manner that although the gravel was excavated from beneath the cylinder to a depth of 3 feet and additional weight was added in the form of water on the deck and piles of brick upon the rim, it did not drop until all the air-pressure had been removed and the earth at the sides of the cylinder commenced to heave inward. This passage of gravel or "heave" from around the cylinder and about the sheathing down and into the void excavated and into which it was desired to drop the structure caused trouble throughout the entire lowering of this shaft, also until the tunnel was completed about 10 feet from the side or eye. Often after working for an entire shift, when air pressure was removed, a net gain in depth of only 1 foot was made, while at other times only 3 inches were gained.

Poling boards were used beneath and in the rear of the cutting edge to hold back the material which had a decided tendency to heave, but with little effect. In some instances over 4 feet of sand and gravel rushed in when the pressure was removed, requiring nearly an entire shift of work to remove it.

In order to increase the weight of the cylinder, hundreds of tons

of pig-iron were placed upon the deck and walls in the endeavor to drive the cylinder down, but even under this added weight it still remained firm.

The sand used as a guide had shifted and the surrounding ground settled or slumped, carrying sheathing and channel-iron rings with it to such an extent that the head-house was unstable, a cavity extending nearly 10 feet from the cylinder in all directions being open. Heavy timbers were placed to span the hole and support the superstructure, being held together with heavy chains.

It was decided at this time to drive a square set of sheathing outside the circular set originally placed, in an attempt to reach the channel-iron rings which were evidently jammed between the steel cylinder and the original sheathing; also to support the earth and prevent further caving. This was accomplished with considerable difficulty, it being found that the rings were in close contact with the cylinder, being much lower on one side of the cylinder than on the other; also that the heads of a few of the rivets used in making the joints of the cylinder had been entirely cut or scraped off as it had slid through the ring. Two rings were cut and the accessible portions removed, after which a boulder that had slid in and bound against the cylinder was broken and removed.

The work of excavating was recommenced beneath the cylinder after sections of the tube leading from the air-lock to the deck had been placed in position, and the cylinder was lowered after continued and discouraging efforts, as at no one trial did it go down more than 20 inches.

Grade lines were drawn across the cylinder on June 23 and preparations made for a final drop to the required grade. After the air pressure was removed the structure settled gradually, and when the desired point was reached, the air pressure was applied, but before there was sufficient pressure to counteract the weight, it had settled nearly 1 foot below the line.

A space was immediately excavated below the cutting edge and poling boards placed in such a position as to allow for the placing of a concrete foundation of much larger diameter than the cylinder. The center of the excavation was dished to a depth of 8 inches below the sides or ends of the poling boards, the material at the bottom and upon which the foundation was placed consisting of a mixture

of coarse and fine hardpan gravel, in which, on account of its firmness, it was difficult to make an impression with a pick.

A pressure of 17 pounds per square inch was maintained while depositing the concrete for the foundation, placing the waterproofing, and until the whole mass had firmly set; the cavity around the shaft was filled and preparations made to extend the walls of the shaft upward.

The power plant upon this work July 1 consisted of three boilers, including the one used in connection with the hoisting engine, all being piped together and making a total of fifty horse-power to operate the hoisting engine and compressor. At this time it was decided to make a trial of the use of cement grout to harden the ground through which the tunnel was to be driven. A small 2-inch opening was made in the steel cylinder in the upper part of the eye 12 feet in diameter, which had been left free from concrete when the walls were formed, a thin mixture of grout was prepared and an attempt made to force it into the sand and gravel surrounding the steel casing, but after several attempts the idea was abandoned, as it seemed, under existing conditions, impracticable, it being only possible to solidify a very small section of the material directly surrounding the delivery point of the grout.

As the excavation was progressing at the different levels, corresponding to those through which the tunnel was to be driven, careful examination was made, with the result that when it was found that the solidification method was impracticable, recourse was had to the original method of using steel plates to support the earth above and upon the sides of the tunnel, while the masonry walls were placed with the aid of compressed air. A supplementary agreement was drawn and the contractor granted permission therein to use steel plates in place of ring timber provided that the masonry walls, including the waterproofing and plaster, were constructed to a minimum thickness of 18 inches; a thickness equal to the proposed ring-timber and brick wall. This agreement was signed, plates ordered, and preparation made to cut out the eye. On July 3 a 50 horse-power upright boiler was added to the existing plant. The work of cutting the steel cylinder progressed very slowly on account of the disadvantages under which the men labored, the positions necessarily occupied in

holding and striking the points being decidedly awkward. After about 170 hours of continuous work by entire shifts with diamond points, a part of the upper portion of the eye was removed and it became evident that the channel-iron rings which were mentioned as having been used as a support for the original sheathing were to continue to disturb operations. Directly across the opening made in the side of the cylinder two of the rings were found twisted completely around each other, having been carried down at least 18 feet while in close contact with the cylinder, thus causing friction which retarded the settling of the cylinder. The sections of rings spanning the eye were cut out and the excavation continued.

As there was no clay encountered in this work, the necessary amount of clay was hauled from the location of an old clay pit near the corner of Bond Street and Western Avenue, a distance of about 800 yards. This clay was not of the best quality for this work but was as good as could be readily procured, the disadvantage in its use being that upon application to the gravel breast and plate-joints it dried, causing crevices to immediately appear through which the air freely issued; consequently, it was necessary to keep men continually employed dampening and renewing the clayed surface.

On July 12 the need of an addition to the air compressor plant was noted; as the small high-pressure engine delivering about 300 cubic feet of air per minute seemed to be inadequate, the temperature in the heading rising to such a degree that an effort was made to cool the air with water and ice previous to sending it into work, and thus enable the men to work freely. The opening in the top of the eye was only 18 inches in depth at this time, and on account of the loose nature of the ground the single compressor was working to its full capacity in order to maintain sufficient pressure to keep the water away from the breast.

A few small boulders were encountered in this first opening, which were removed without difficulty. For four full days, or eight shifts, the men labored in excessive heat, depending upon the one compressor, and succeeded in driving the arch of the tunnel a distance of four plates, or 4 feet from the side of the vertical shaft. After two more rings were added it was decided to

suspend operations and seal the heading with clay until another compressor could be installed, as it was decidedly dangerous to excavate further and depend on the one compressor then operating at its full capacity to maintain the required pressure.

On July 22 another high-pressure compressor capable of delivering about 800 cubic feet of air per minute was installed and in operation, working in conjunction with the other, and the work was again rushed forward.

The contractors at this time realized the necessity of still further increasing the plant by the addition of another boiler, as the three small boilers on the work were taxed nearly to their entire capacity. When the arch had been driven a distance of 8 feet the needle-beam, consisting of a timber 10 feet in length, 12 inches square, was placed in position, and the work of removing the lower half of the eye of the cylinder was commenced. The plate-joints and breast were completely covered with successive coatings of clay to hold the air, and even then it required the operations of both compressors at a high speed to maintain sufficient pressure, the thermometer registering 100 degrees in the heading and 90 degrees in the lock. The continuous labor (eleven hours) in humid compressed air at such high temperature began to affect the laborers and they were obliged to come out through the lock at intervals for change of air. On July 27 the brick masons laid the first section of invert and completed the arch and work around the eye on July 29, laboring in the intense heat nearly forty-five hours to complete the section 6 feet in length.

A temporary bulkhead of plank and bags of clay was placed in the invert at the end of the completed section, and the heading again opened. While this work had been progressing, another boiler (capacity 150 horse-power) had arrived, the entire plant being connected and in working order on August 3; the heading had now been extended a distance of 12 feet through coarse gravel and boulders. At this time the larger of the two compressors became jammed and was out of commission for a few minutes, the whole load resting on the small compressor. During the strain this compressor turned 140 revolutions per minute, and although the pressure gradually dropped, the single engine held sufficient pressure until the defect was repaired and both were running.

PLATE II.

HEADING AND BENCH.

It was evident to the writer that there was not a sufficient duplication of plant upon the work, and in consequence he requested the contractors to still further add to the existing plant a compressor delivering at least 1100 cubic feet of air per minute. Under the conditions, it was unsafe to carry on operations in the heading, not only on account of the danger to the laborers, but also on account of the danger of loosening or the caving in of the breast and the loss of time in again recommencing operations.

On August 16, 26 feet of the walls of the tunnel had been completed, and the contractors had decided to send a third compressing engine to the works, had procured a large low-pressure machine, capacity 1100 cubic feet per minute, and assured the writer that it would be in operation within a few days.

At various times during the progress of the work, the Board of Water Commissioners viewed the work, passing the air-lock with slight difficulty. A few others who were perhaps especially interested in the nature of the work or the methods used, succeeded in reaching the lower levels under pressure, but the majority of the citizens preferred to keep at some distance from the works, being satisfied to inspect the men as they emerged from the outer door of the lock in a cloud of steam.

The contractors kept in touch with the work, and knowing well the delicacy of the operation of driving the tunnel through the coarse gravel and stray boulders that might be encountered, suggested a decided change in the method of construction. Under the bed of the canal the roof of the tunnel was to be constructed within 11 feet of low-water mark, the bed of the canal being practically dry at low tide. The amount of material above the work was deemed insufficient to hold sufficient pressure to allow for the construction of a full section of the tunnel wall; therefore it was decided that when the completed walls had been erected to within a safe distance of the canal, the upper half or arch should be driven and the arch wall completed under and as far as the westerly side of the canal to a point beneath the retaining wall.

The last addition to the plant consisted of a large low-pressure compressed air engine, having a capacity of 1100 cubic feet per minute, and was installed and in operation on August 23. It was found that the difference in the temperature in the tunnel was

about 20 degrees, being much lower than when the air was supplied by the small compressors; it was also noted that sufficient air could be supplied by the new engine and half speed on the second machine, allowing for repairs on the third or smallest engine.

The work hereafter progressed more rapidly, and on August 28 46 feet of the tunnel wall was completed, and on September 1 a gain of 10 feet additional had been made.

At a point about 56 feet from the easterly shaft a temporary bulkhead was erected, filling the bottom of the tunnel or invert to within a few inches of the spring line, composed of a brick wall 12 inches in thickness and backed by clay puddle. This dam or bulkhead remained in place until the arch walls were completed under and beneath the western walls of the canal. During the construction of this arch about 9½ pounds of pressure was sufficient to carry on the work. When the tunnel had been driven to a point within 20 feet of the easterly canal wall a slight leakage of air was noted in the waters passing through the canal. This disturbance continued to increase as the work was extended, and when it had progressed to a point directly beneath the canal, the air rushed up through the waters in such volume from the heading that the canal for its entire width and a distance of 50 feet up and down stream resembled a boiling caldron, which was watched with much interest and speculation by large numbers of people from the bridge.

This work of driving the arch had progressed only a few feet when a boulder was uncovered in the roof extending across the heading for a distance of 5 feet and hanging into the opening about 2 feet. A few light charges were fired in small hand-holes made on the under side of the boulder, but no marked effect was made. Drilling and splitting was then commenced, and after nearly a week of continuous work the roof-plates were made secure beneath the stone, a sufficient amount of the boulder having been removed. Several small boulders were found, split, and removed from the heading, remaining in the completed tunnel until the air deck was removed, as they were too large to move through the lock.

During the progress of this part of the work the ground occupying the position of the invert remained undisturbed, the bench or

PLATE III.

HEADING. TUNNEL NEARLY COMPLETED. INVERT UNDER CONSTRUCTION.

ground below the spring line being covered with a layer of clay 6 inches in thickness, having an overlayer of boards. It was quite a difficult task and required continuous watching to keep the pressure at an amount sufficient to keep the water from entering under and through the clay floor, and again not enough to lift the canal bottom and cause a blowout, it being necessary to watch the rise and fall of the tide and regulate the pressure according to its different levels.

During this part of the work the smallest error in air pressure could but result in severe monetary loss to the contractors and possibly the loss of the lives of the men employed in excavating the heading. The materials excavated were coarse sand and gravel, through which the air rushed freely when not retarded by the coating of clay applied from within, and was removed from its original position by small trowels. This gravel, after being dug out with the trowels and dropped on the bench, was shoveled into a single wheelbarrow and transferred to the shaft. Here it was again shoveled into a bucket to be lifted into the air lock. From the lock it was dumped in carts and hauled to the dump. Thus it will be understood that the gravel excavated was handled five different times before being finally dumped, making the expense heavy.

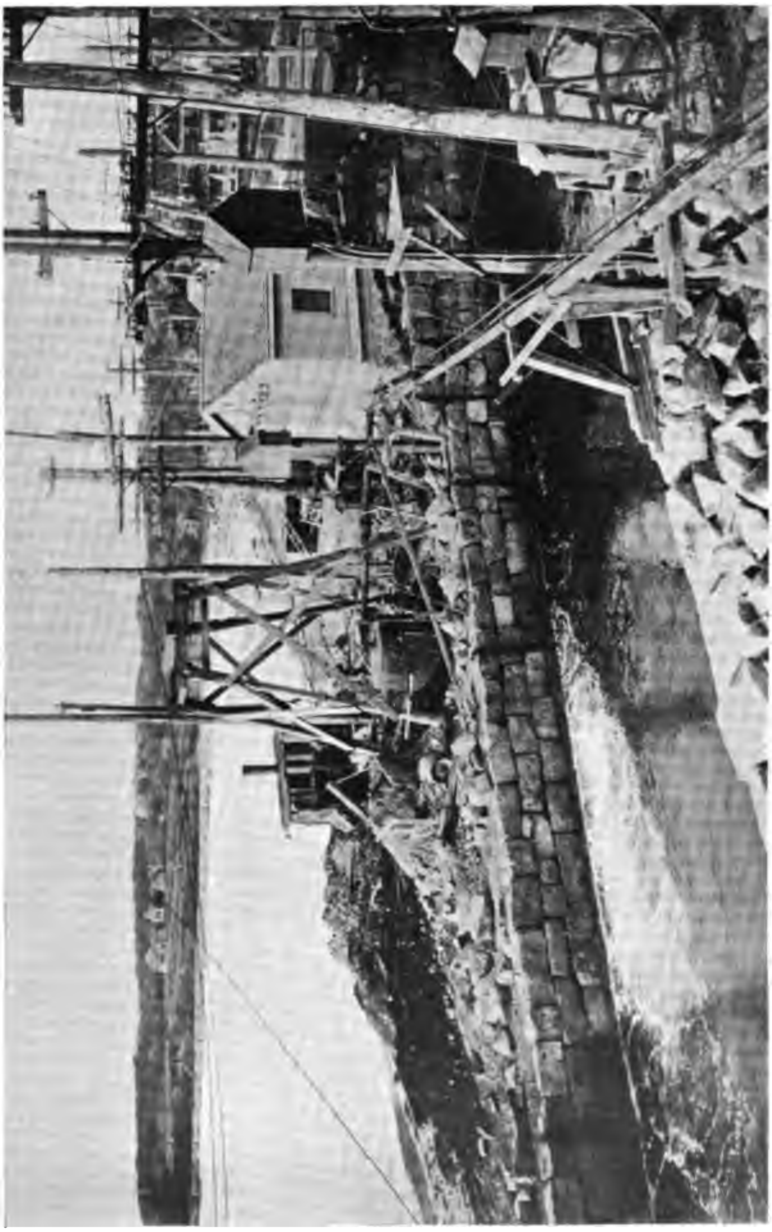
Several times during the perilous part of the work on the arch, the earth was driven upward by the air pressure or fell away, leaving a large aperture through which the air roared to the surface. During these periods the whole compressor plant was operated to its entire capacity; these voids were immediately filled with clay, bags, or any cloth or material which would stop the outrush of air, the miners knowing that were these voids not filled at once the pressure would relax and the waters from the canal and the harbor rush in. On September 21 the arch was completed to a point about 14 feet from the western shaft and beneath the westerly side wall of the canal, and a solid brick bulkhead erected. This bulkhead was built within the completed arch and about 1 foot back from the toothing, thus leaving sufficient brick work for connection with that part of the tunnel which was to be built from the westerly shaft.

The first temporary brick bulkhead was now removed and the

invert constructed, the connection between the arch and invert being made tight by splitting brick in form of a wedge and driving tight. This being neatly executed, the circular section was made complete to the terminus of the work to be accomplished from the east side. The bulkhead having been completed and braced by heavy raker timbers stepped into the brick invert, the air pressure was removed and the air tube and lock transferred and fastened in position in the west cylinder, the air and water supply pipes were suspended over the canal, the head-house placed in position, and the work of settling the western shaft commenced on October 6.

The west cylinder, having timber guides, settled rapidly, the cutting edge being kept in contact with the bottom, slipping down when the air pressure was slightly reduced; thus the trouble of the heaving of gravel, as was experienced in sinking the east shaft, was avoided, and on October 9, 12 feet of progress downward had been accomplished. On October 13 the cylinder reached the required level and the concrete walls were extended upward toward the surface. The excavation was made and foundation placed similar to that in the east shaft, and the work of cutting out the eye of the tunnel in the steel cylinder commenced. The levels and lines were transferred through the deck and preparations made to excavate for the arch. This work was commenced on October 19 and six days thereafter the toothing of the completed section and bulkhead was met, and on October 30 the continuous walls of the tunnel were complete from the east to the west shaft. The work of calking, cement washing, and finishing was begun immediately after the bulkhead was removed; the fires were drawn in the larger boiler and it was removed. On November 4 the night shift was discharged, the work thereafter being carried on by one gang during the day. Three days thereafter the air pressure was withdrawn, and the writer was gratified to note that there were very few damp spots throughout the entire length of the tunnel. Several small leaks appeared in the west shaft which were readily stopped when the air pressure was again in use.

The drains from the west shaft to the east shaft were laid, above which the ducts (six lines of six multiple vitrified duct) were laid



SITE OF TUNNEL, AND CONTRACTOR'S PLANT.
This view was taken when making the connection between the two headings.

in the invert or bottom of the tunnel, air pressure of 15 to 20 pounds per square inch being maintained until all were in place and covered with concrete. These six lines of duct were divided into two sections, being imbedded in the concrete, the joints waterproofed, and separated by a wall of concrete 1 foot in thickness, one side to be occupied by high tension, the other by low-tension cables; the concrete covering was overlaid with fine plaster, which serves as a floor.

The pneumatic pressure was finally removed on November 16 and members of the Water Board inspected the structure, together with the writer, and expressed satisfaction with the work, the total leakage being unusually slight.

The water mains, two lines of 20-inch cast-iron pipe, were next placed above the floor, supported upon brick piers on either side of the tunnel, the 12-inch gas main being supported in like manner in the center. These lines of pipe were extended up through that portion of the shafts designed for their occupancy, and the partition walls erected.

The ducts were wired, a line of wire extending from one shaft to the other through each duct to serve as a lead wire when placing the cables later.

The reinforced concrete roofs or covers were laid and the manhole caps and covers placed in position, the grounds around the shafts were graded, and the tools and machinery removed. The Board visited the tunnel on December 22, together with the writer, and after a thorough inspection, decided that the difficult task of building a practically waterproof tunnel and appurtenances under numerous disadvantages had been acceptably completed, and upon the following day the contractor was notified of the acceptance of the work.

The leakage of the tunnel and shafts is at this time much less than in any tunnel now completed in this country of which the writer has knowledge, being less than one-half gallon per minute, with evidence that this will be reduced in the future. When the material through which this work was built is considered, together with the several obstacles encountered, the contractor is to be congratulated upon the success of the undertaking and the fact that no person was injured during the work. The absence of

leakage in the brick walls of the tunnel is due in part to the excellent work of the two masons, George H. Eaton and Michael Ferriter, who laid up the walls under pressure and in extreme high temperature, and whose work, accomplished under the several difficulties, is certainly commendable.

To Mr. Charles B. Lewis, who acted as foreman in charge of the work for the contractors, is due the credit for close and unceasing care in the handling of all parts of the work, and of completing a wholly satisfactory piece of work.

The entire engineering work connected with this tunnel, viz., location, design, drafting of plans, including all general and detail plans, together with the drafting of the contracts, was executed by the writer in person, who also acted as resident engineer and inspector during construction, the only assistance required being furnished by the timekeeper and foreman employed by the contractor as per the terms of the contract.

A small vertical centrifugal pump was submerged at the bottom of the collection sump, being operated by an electric motor located directly beneath the roof of the shaft, the connection between pump and motor being made by a shaft bracketed to the side walls.

A float and automatic switch were included in the appurtenances to the pumping plant, and the water collected is of such small quantity that the automatic action of the pump occurs at intervals of fourteen days.

When the structure has been closed for a considerable time, moisture of condensation collects in the arch and upon the mains, which finally reaches the sump, but when the manhole covers are removed and a strong draught is allowed to circulate for an hour, the walls of the tunnel and shafts are sufficiently dry to allow the lighting of matches on the cement-washed surfaces.

Electric cables have been installed in the ducts, the gas and water mains have been in constant use practically since the acceptance of the work, and no trouble has as yet been noted; hence the practicability of a small sub-aqueous tunnel for the location of water and gas mains together with electric cables has been demonstrated to our entire satisfaction.

PLATE V.

COMPLETED TUNNEL.

A CITY'S RIGHT TO METER PRIVATE FIRE SERVICES.

SHAW STOCKING COMPANY *v.* CITY OF LOWELL.

Supreme Judicial Court, Massachusetts, Middlesex, May 22, 1908.
(85 Northeastern Reporter, 90.)

SHELDON, J. We see no reason to doubt the authority of the water board of the defendant city to make the regulations here in question. These regulations require that all water supplies from the city's mains to the premises of any water-taker for the purposes of a private fire system shall pass through a meter, and that this meter shall be furnished and set by the city at the expense of the owner of the premises served.

Authority to supply water to its citizens was first given to the city of Lowell by Stat. 1855, Chap. 435. The third section of this act empowered the city, among other things, to construct and maintain proper aqueducts and pipes, to establish public hydrants, to prescribe the purposes for which they should be used, and to change or discontinue the same; to distribute the water throughout the city and to regulate the use of said water, and establish and collect the prices to be paid therefor, and also to do any other acts or things necessary or convenient and proper for carrying out the provisions of the act. Additional statutes have since been passed, but the power and authority of the city have not been diminished by any of them. See Stat. 1866, Chap. 200; 1869, Chap. 351; 1870, Chap. 321; 1893, Chap. 412; 1895, Chap. 247.

By Chapter 45 of the Revised Ordinances of Lowell, the powers thus given the city have been vested in its water board, in pursuance of the permission given by Stat. 1855, Chap. 435, Sect. 5.

The defendant has not required and does not purpose to require in future any payment for water used in extinguishing fires. The principal object of the defendant's water board in requiring fire-service pipes to be metered is to prevent the surreptitious or careless withdrawal of water through such pipes for other purposes than the extinguishment of fires; another object is to procure the

measurement by meter of all water consumed for any purpose in order to check wastage and to require each taker to pay for the exact quantity of water furnished to him. The requirement is well adapted to aid in accomplishing these objects; and this is none the less so, although its operation sometimes may be circumvented by some fraudulent device. The regulation must be regarded as reasonable unless some of the plaintiff's specific objections to it can be sustained.

The plaintiff contends that it ought not to be required to pay for the meter to be applied to its private fire service pipes. Its counsel relies upon the decisions in Red Star Steamship Company *v.* Jersey City, 45 N. J. L. 246; Albert *v.* Davis, 49 Neb. 579; Smith *v.* Birmingham Water Works Company, 104 Ala. 315; Spring Valley Water Works *v.* San Francisco, 82 Cal. 286, 316; and Sheffield Water Works *v.* Carter, 8 Q. B. D. 632. But these cases differ from the case at bar. They generally turned upon the language of the statutes under which they arose, or the provisions of the contracts which were before the courts. In this case it has been found by the court below, with evident correctness, that the defendant is under no legal obligation, by contract or otherwise, to furnish the plaintiff with water for its private fire-service system. Under the present circumstances, we prefer, so far as it is a matter of precedent, to follow the carefully reasoned opinions in Sheffield Water Works *v.* Bingham, 23 Ch. D. 443, in which the earlier case of Sheffield Water Works *v.* Carter, *ubi supra,* is fully discussed; and State *v.* Gosnell, 116 Wis. 606, decided in 1903, in which the earlier decisions are reviewed. Both upon principle and authority we are of opinion that under circumstances like those before us it is not unreasonable to require the installation of a meter at the plaintiff's own expense in its private fire-service pipes.

Nor can it be said that this regulation imposes undue burden upon the plaintiff. The defendant has afforded reasonable means of extinguishing fires by public hydrants; if the plaintiff desires in addition a private system for the protection of its own buildings, it is not unfair for the defendant to impose, as a condition of supplying without other charge water to make this system available, the requirement that the plaintiff shall take this water only through a meter to be put in at the plaintiff's expense. The defendant's

duty to supply water at reasonable rates to all takers without discrimination, so far as this duty exists (see Merrimack River Savings Bank *v.* Lowell, 152 Mass. 556, and Lombard *v.* Stearns, 4 Cush. 60), does not carry with it any obligation to supply water free of charge for the plaintiff's private system of safeguarding its property.

Nor has there been unjust discrimination against the plaintiff in the enforcement of this regulation. The rule is a general one, applicable to all persons who maintain a like private system. That it has been put in force only gradually, beginning with the worst or the most important cases, affords no reason for enjoining its enforcement in any particular case. Parker *v.* Boston, 1 Allen, 361. Ladd *v.* Boston, 170 Mass. 332. Wagner *v.* Rock Island, 146 Ill. 139.

Accordingly, the decree of the Superior Court dismissing the bill must be affirmed; and it is

So ordered.

METERS AND WATER CONSUMPTION OF THE HARTFORD WATER WORKS.

BY ERMON M. PECK, ENGINEER IN CHARGE OF MECHANICAL DEPARTMENT, HARTFORD, CONN.

[Read September 24, 1908.]

When the big new Tumble Down Brook Reservoir was completed in 1895 it was predicted confidently by many wiseacres that Hartford would not need another reservoir for many years to come. The population of the city at that time was about 66 500.

In December, 1899, only a little more than four years later, with a population of about 80 000, or only about 13 500 greater, the city suddenly found itself confronted by one of the worst water famines in its history. To produce this condition of affairs two factors were dominant, viz., unfavorable occurrence of rainfall and consumption greatly in excess of its needs. In this exigency the hustle gong was sounded for the construction department and in record-breaking time, pumps, boilers, intake, and a new force main were installed only to " die a-bornin' " ; for, with all the irony of fate, on the very day upon which the new plant was to be tested, Jupiter Pluvius deluged the earth, and Hartford's latest water famine passed into history. In the meantime, however, for several weeks the decrepit old pumping plant which had been used to supply the city from the Connecticut River nearly half a century before had been started into action and limped along until one morning, crystallized from many years of overstraining, the piston rod of its engine broke and the fortune of the Hartford Water Department looked darker than ever. The Hartford Street Railway Company was our good angel in this dilemma, and its general manager very kindly furnished and installed a motor to operate the pumps, so that in a few hours we were able to force filthy Connecticut River water into our mains with as much gusto as formerly, and continued to do so until the occurrence of the storm noted above.

When the drought was broken and our nervous system was

relieved of the temporary strain it was evident that something must be done.

The department had two inspectors who regularly covered the city twice per year on the assessment plan, and while these men knew that many leaks existed and that gross abuse prevailed along the line of permitting faucets to run to prevent freezing of pipes in very cold weather, their duties were too arduous to allow them to make detailed inspection for the purpose of detecting these sources of waste. Accordingly, 10 additional inspectors, one for each ward, were employed, who shortly gave good accounts of themselves by the number of premises where water waste occurred which they reported. These reports, coupled with the recent shortage, spurred the board of water commissioners on to adopt the policy of general metering of service pipes. It was planned to complete metering the city in about three years, and this was very nearly accomplished.

The following table is an exhibit of the number of meters in use and the daily per capita consumption by years. The 84.6 gallons per capita opposite the year 1900 may be taken as the best information we have of the per capita consumption previous to general metering, and was computed from scattering Venturi meter readings. In 1902 the automatic register was attached to the Venturi and since that time the records are reliable.

Year.	No. of Services in Use.	No. of Meters in Use.	Per Capita Consumption, Gals. per Day.
1900	8 951	550	84.6
1901	9 256	2 783	76.3
1902	9 514	6 993	78.8
1903	9 683	9 156	75.0
1904	9 809	9 604	66.7
1905	10 006	9 860	62.6
1906	10 328	10 137	61.6
1907	10 623	10 433	59.1

These figures are based upon the total population supplied, which at present is estimated to be divided as follows:

Estimate of population in Geer's 1907 Hartford Directory	106 000
Population supplied in the towns of West Hartford, Wethersfield, and Bloomfield	3 000
Floating population, equivalent to regular consumers	4 000
	113 000

The estimate of the floating population was arrived at by stationing observers at the outskirts of the city on the various trolley lines to count the passengers bound cityward. Similarly observers were placed at the Union Railroad Station. Each "floater" was estimated as one-third regular consumer.

At the present time the department has 10 922 services and 10 814 meters, 99 per cent. of the taps being metered. This is a high percentage compared with that of most other cities.

It should be said in this connection that the above reduction in the consumption of water has not been accomplished by meters alone, but partially by a rigid waste and leak inspection which has gone hand in hand with it. Inside the premises the inspection has been prosecuted by the meter readers. In the streets the water mains, services, hydrants, etc., have been inspected regularly by parties of men who did nothing else. The early experiences of this leak survey party were marked by the discovery of many leaks, some large and of long standing. The leak survey was established in 1902, but did not operate extensively until 1904. The large drop in consumption for that year I consider largely due to its work.

The rise in consumption in 1902 I consider due to the fact that the "big bill bogey," always easily conjured by the excited mind of the water taker, had failed to materialize, and the reaction towards increased consumption usually noted in such cases had set in. This, of course, was cut down in the succeeding years by fighting waste and leaks.

In this connection I may say that a very interesting computation was made during the past year, designed to show the proportion of the water passing the Venturi meter at the distributing reservoir which could be accounted for. After making proper allowances for unmetered water and under-registration of meters, it was found that only 16 per cent. of the water as registered by the Venturi remained unaccounted for. Since that time several of our fire service pipes have been metered, with the result that this percentage could be somewhat reduced.

Recently the board of water commissioners has become impressed with the importance of systematic tests in order to keep the meters within permissible limits of registration. We require

all meters to test not lower than 98 per cent. and not more than 100 per cent. on full flow.

All new $\frac{5}{8}$-inch, $\frac{3}{4}$-inch, and 1-inch meters are required to register 75 per cent. on a $\frac{1}{32}$-inch stream under the pressure at our testing bench, which would be equivalent to a flow of .0230 cubic feet per minute, and after they have been in service they are required to register on this flow. It is the intention to test all meters at least once in four years, and perhaps oftener.

Meters larger than 1 inch are required to test more in accordance with the service for which they are used than by a fixed rule, although, as a general proposition, $1\frac{1}{2}$-inch and 2-inch meters, after being in service, are required to register 50 per cent. on a $\frac{1}{16}$-inch stream, — a flow of about .113 cubic feet per minute, — the other requirements being the same as for smaller meters. The larger part of the meters above 2 inches in size are being fitted out to be tested in place. This is done by putting a valve in front of the meter with a hose connection between the two. To test the meter, the valve on the service is closed and the hose connected up with an accurate meter in series with the one to be tested as in the following sketch. (Fig. 1.)

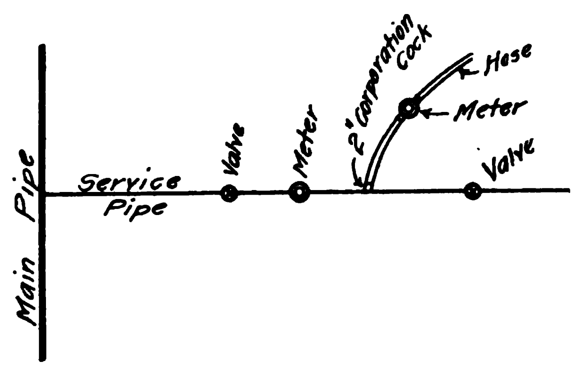


Fig. 1.

In laying new services the following plan has been adopted (see Fig. 2): *A* is a valve on a by-pass around meter. This valve is closed and locked at all times excepting when meter is being tested.

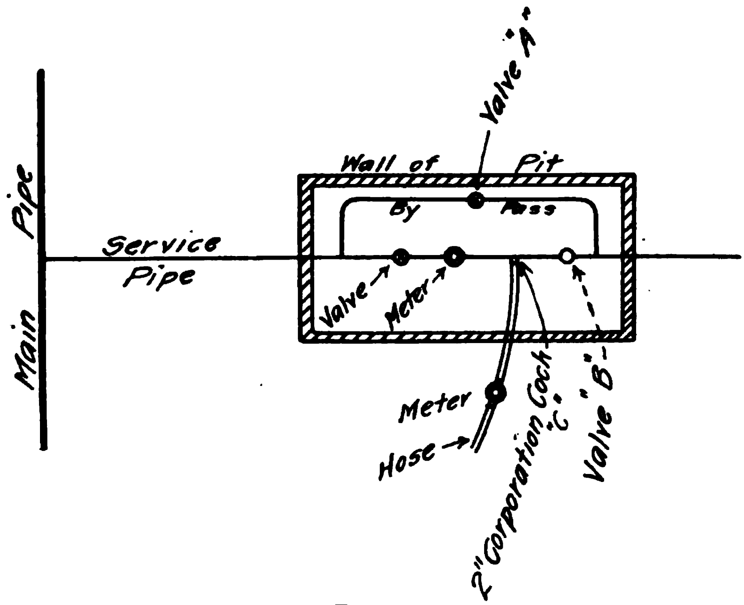


FIG. 2.

B is a valve in front of meter, and *C* is a corporation cock for connecting up hose with accurate meter. To test meter, hose is connected up as in the sketch above. Valve *A* is then opened and valve *B* is closed.

The whole arrangement of valves and by-pass is placed in a concrete pit. By this method, large meters can be tested without shutting off the supply from the consumer, which is often a great consideration.

Although this method of testing large meters has been in use for some time in other cities, it has not been employed in Hartford any more than experimentally to ascertain its practicability until recently. A party of men was at work for some time during the past winter fitting up the larger services for these tests.

It is our intention to test all the meters so arranged at least once each year, and in some cases twice.

The meter card which has been lately designed for the Hartford Water Board, is a large one, being approximately 9 inches by 14 inches. It is ruled and printed on both sides, one side being

devoted to information regarding installation and the other to maintenance. An 18-inch Elliott-Fisher billing machine is used for writing up the cards.

The writer may add that the card system has been adopted recently for the meter readers' books, and these, too, are written upon this machine.

DISCUSSION.

MR. ALLEN HAZEN.* I should like to ask Mr. Peck if he has ever made a calculation of the amount of water used for manufacturing purposes that is drawn from other sources than the supply pipes. That is, of itself, a very important matter, and I know that in Hartford a great deal of water is drawn from the streams for manufacturing purposes, in addition to what comes from the public supply; and wherever the per capita consumption is stated, I think that it is important to have go with it a record or statement of what the conditions of the use of manufacturing water are.

MR. PECK. That is a question which came up about a week before the meeting, but we had no means of answering it. We are liable to have to make some estimate of it before a great while, but at present I cannot give it. It is a large amount of water; there is no question about that.

MR. HAZEN. The factories draw the greater part of their water from other sources than your supply; that is true, isn't it?

MR. PECK. Some of them do, not all of them; I would say a large part of them.

MR. M. N. BAKER.† Has there been any material change since you began metering in the amount that manufacturers take from other sources?

MR. PECK. No, I do not think so. I do not think it has been affected at all by putting on meters.

MR. H. N. PARKER.‡ I should like to ask why you took the consumption of the floating population as one third. Is that

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* Of Hazen & Whipple, Consulting Engineers, New York City.

† Associate Editor *Engineering News*, New York City.

‡ Assistant Hydrographer, United States Geological Survey, Washington, D. C.

based on any estimate of time that a visitor to the town was likely to stay there, or what reason was there for using that figure?

Mr. Peck. That is just what I based it upon. I tried to hit upon some scheme for fixing a value for the " floaters," and I arrived at it in that way, by considerng, perhaps, that the proportion of the water they would use would correspond with the time spent in the city.

The President. Perhaps it might be interesting if Mr. Peck would tell us whether he is using many detector meters on the fire services, or how he meters those.

Mr. Peck. We have a few detector meters in use.

METER RATES.

BY WALTER H. RICHARDS, ENGINEER AND SUPERINTENDENT, WATER AND SEWER DEPARTMENT, NEW LONDON, CONN.

[*Read September 24, 1908.*]

The subject of meter rates has been much discussed, both in this Association and others, but a few points remain to be brought out in an otherwise threadbare subject, and it is with this in view that this paper is introduced.

Up to this time meters have been installed primarily to prevent waste, and there is no doubt that in this particular the meter is successful. But as was so clearly shown in Mr. Johnson's able paper,* the per capita use is constantly on the increase, due to the legitimate consumption through an increased number of fixtures and from other causes. The per capita consumption varies considerably with the character and habits of the population; for instance, Woonsocket, with 91 per cent. of its services metered, has a per capita consumption of 29 gallons per day, while Newton, with 86 per cent. of its services metered, has a per capita consumption of 54 gallons.

But is it not time that we plead for measured water on the ground of equity? Why should any intelligent engineer of water works undertake to defend the so-called schedule rates which, if he is well informed, he knows to be full of inconsistencies?

If it is argued that it costs no more to procure and deliver two gallons than one, the argument fails when we apply it to larger quantities, as it often costs as much to increase the supply to a city by 100 per cent. as the amount expended for the original work.

If the installation of meters is deferred on the grounds of economy, it is clearly a subterfuge, and an injustice is resorted to, to save the cost of the necessary machinery to " deliver the goods," for the meters are undoubtedly a part of the water-works plant. To say that all stores, markets, or barber shops use like quantities,

* JOURNAL N. E. WATER WORKS ASSOCIATION, Vol. 21, p. 109.

or even that any two use like quantities, is absurd. To charge for the supply of one fixture the same as another, regardless of the number of times it is used or the length of time it is used, is clearly neither scientific or equitable. The use of meters has demonstrated that one party may use double the quantity of water that another does under precisely the same conditions, and even were this not true, the constantly increased number of uses to which water is put renders the formulation of a schedule rate for each kind and each size of fixture used by a different number of persons for different purposes entirely impracticable. Water should be sold, therefore, like other commodities, according to the weight or volume.

The charge for water, like any other commodity, should be based on its cost, and as the cost is different in different places, it follows that the rate should be different, and if the water department were conducted on an independent and on a business basis, that rate should not be below cost.

The cost of water in various cities, as shown in the following table, is obtained by dividing the total cost of maintenance and repairs, including interest on bonds,* by the total amount of water flowing into the city. This table shows great variation, the price varying from 1.8 to 0.27 cents per thousand gallons. As in some cases, however, a considerable portion of the cost of the works has been paid from the income, it is a question whether this method can be fairly used to ascertain the cost of the water; it would seem right to calculate interest on the net cost of the works; furthermore, it has been found that about 40 per cent. of the water going into a city is lost by leakage or from undiscovered wastage before reaching the consumer; hence only 60 per cent. of the entire flow should be considered.

ACTUAL COST OF WATER PER THOUSAND GALLONS SUPPLIED.

Atlantic City, N. J.	$0.0723
Battle Creek, Mich.	.072
Bay City, Mich.	.0315
Billerica, Mass.	.1768
Cambridge, Mass.	.0659

* JOURNAL N. E. WATER WORKS ASSOCIATION, Vol. 19.

Chelsea, Mass.	$0.0442
Cleveland, Ohio	.0232
Haverhill, Mass.	.04
Lawrence, Mass.	.089
Lowell, Mass.	.1667
Lynn, Mass.	.10
Marlboro, Mass.	.1345
New Bedford, Mass.	.047
New London, Conn.	.0546
Oberlin, Ohio	.1153
Reading, Mass.	.27
Reading, Penn.	.018
Taunton, Mass.	.0983
Waltham, Mass.	.0637
Westerly, R. I.	.0878
Winchendon, Mass.	.2302
Woonsocket, R. I.	.1342

The problem, therefore, is to find the cost of water which can be delivered to customers without additional main works, from which the rate should be fixed so as to furnish, with other rates and charges, a sufficient income to provide for the payment of all interest charges and the maintenance of the works, together with such unforeseen expenditures as may be required for small extensions or additions to the works, and for expenditures due to accidents which cannot be foreseen.

A large percentage of the cost of the works is due to the increased size of the mains, fire hydrants, etc., which are necessary for fire protection, and which are for the benefit of the general taxpayer. Water for schools and public institutions is in the same category, and all this should be paid for from the tax rate. Other than the above, the taxpayer, as such, should have but a small part of the expense of maintenance of the water system.

So far as extensions of mains is concerned, after the main portion of the city has been piped, it may be provided for by the guarantee in water rates, on the part of abutting property, of a reasonable percentage on the cost of a small main of size sufficient to supply that street (say 6-inch) until such time as the regular rates amount to this guarantee.

The cost of the meter itself and the cost of setting the same must be provided for and should be a charge on each meter

sufficiently large to pay cost of repairs due to wear and breakage from frost and for renewals after the meter is worn out. Very few data are available on this subject. A charge of 10 per cent. on the cost is the rule at present, which is probably too small. The practice in some cities of charging the cost of meter and repairs to the consumer does not appear to be desirable, as the meter is a part of the water-works system and should be always under the control of the department, and to charge the cost to the consumer is simply another way of increasing the expense of the water to the consumer.

A uniform charge for all water without regard to the quantity or purpose for which it is used has been suggested, but it should be considered that a considerable portion of the expense of securing the purity of the water is to fit it for domestic use; and further, it costs but little more for service pipe and meter for a large quantity than a small quantity. For instance, a 2-inch service can easily supply as much water as twenty ordinary ⅝-inch services, whereas the cost of the service is but about ten dollars more than the ⅝-inch service.

To cover the cost of connecting with the mains, and other costs which are uniform regardless of the quantity of water used, a minimum rate is desirable. The practice seems to vary between $5 and $10 per annum. The low rate seems to be desirable as encouraging the use of meters.

The formula suggested, then, is: Divide the cost of maintenance, repairs, renewals, and interest on cost of works less that cost necessitated by the fire supply, by the quantity of water the works will supply less the leakage from mains (say 50 per cent.).

To this should be added a constant for unforeseen expenses due to accidents and for such extensions of mains as do not increase the capacity of the works.

From the above it is evident that no comparison should be made between the rates in different cities, and, as a matter of fact, there is a wide difference in meter rates. Few, however, seem to have rates fixed on a scientific basis, and many contain glaring inconsistencies. This is illustrated by the rate which charges one rate for a certain amount used in a given time and a smaller rate if a larger amount is used in the same time, by which a customer,

having used a certain amount, finds he will save money to let his water run. This is sometimes supplemented by an addition to the rule by which, between certain quantities, the same amount is paid.

These forms of rates are illustrated by the diagram, Plate I, "A" being the straight rate, "B" being the rate whereby a consumer gets more water for less money, and "C" being the gradually decreasing rate which gives a parabolic curve. All the curves are illustrations of rates now in use.

No water department manager need think that having decided on the rate his troubles are over, for a host of difficulties arise with every meter set.

How many meters shall be set in a building? If the department sets but one meter on a service pipe, how is the landlord to divide the charge among his tenants? If he is compelled to have a meter for each tenant, who furnishes, sets, and reads these meters? And if the rate is a decreasing rate billed to the landlord, how shall it be divided among the tenants? If the water department reads the meters, shall the department divide and bill to each tenant?

With a decreasing rate, shall the bill be calculated for each service pipe metered or all the service pipe in the building combined, or all adjoining buildings combined owned by the same owner, or all the buildings or supplies in the city owned by the same owner?

It seems best to the writer for the department to furnish, set, and read one meter for each service pipe and let the landlord divide it among tenants as he sees fit.

Where meters are required for certain uses only, shall the meter be set so as to meter all or a part of the building supplied?

While it seems absurd to have the fixtures in one room metered and those in the next room unmetered, these are conditions existing in the writer's own department.

Whether a meter should be set inside a building, in the sidewalk, or on the lawn is a question. To set meters in the sidewalk or lawn increases the expense of setting largely, but avoids danger of freezing and measures all water entering the premises; on the other hand, if set inside the building it is more easily read, especially in cold weather, and can be kept track of by the consumer.

When it is suddenly decided to meter a certain class of consumers, leaving the remaining consumers to pay schedule rates, much friction arises and the installation is made with difficulty, and, in the writer's opinion, it is much fairer and the rule is enforced with less objection on the part of consumers if all supplies are metered without exception.

In presenting this paper no attempt has been made to indicate an exact rule for calculating a meter rate or the charges for meters, but the rule is presented as a guide, each department to be guided by local circumstances. The writer's preference, however, is for a graduated rate as indicated by " C " on the diagram, and the calculation and billing for all the water which enters each separate building to the owner of that building.

DISCUSSION.

THE PRESIDENT. Gentlemen, this paper is now before you for discussion.

PROF. EDWARD W. BEMIS.* Mr. Chairman, we have been experimenting a good deal with meters, as you know, in Cleveland, and we have now perhaps more meters than in any other city in this country. We have about 68 000 meters in use. I should think from our experience that almost all the points which have been made in this paper were sound, with possibly one exception, so far as I noted. That was with regard to the graded system of rates. I think that it is necessary to have your rates so adjusted as to get the revenue necessary for the department, and it may be necessary to have a much higher rate for small consumers than for large ones. It certainly is true that it costs much more for a small consumer, in proportion to the water he uses, than it does for a large consumer; and, so far as the paper suggested a minimum rate, it seems to me that our experience in Cleveland would endorse that thoroughly.

But I was thinking more particularly of the concluding sentences of the paper, in which it was proposed to have a rate which would vary with the amount used. That is practicable, it strikes me, although we do not have it in Cleveland. We have

* Superintendent of Water Works, Cleveland Ohio.

there a uniform rate for all consumers, large and small, although we do have a minimum rate which varies with the size of the meter. It is practical to have two rates, — a rate for the first thousand feet a month perhaps, or the first two thousand feet per month, if you prefer, and a lower rate for all in excess of that. But there is an objection, and a very serious one in my mind, to having several gradations of rates for large consumers. If you simply desire to have a rate for the first one thousand or two thousand feet that shall be much higher than the rate for all in excess of that, you are not doing injustice to anybody, and you are to some extent following out the theory that, since it costs more for the small consumer, he should pay more, for there is a marked difference between the character of the consumers you would hit by your rate for the first one or two thousand feet a month and those who use more. The class that you would hit by your higher rate would be the residences, and such gradation as I speak of would give a lower rate to business properties as contrasted with residences; and, in view of the great difference in the cost of supplying to the two, that does not look to me unreasonable.

The moment you have a series of gradations between business properties, you give the large fish a greater opportunity to swallow the small ones. You then give a wholesale rate to one business man and a retail rate to his small rival in the same line of business.

That is common in private business, and we do not criticise it, — we expect it, — and I do not know, therefore, that I would expect a private water company to do very differently in that respect from a private business in ordinary lines, unless prevented by law. I am speaking more particularly now of a municipally-owned plant, and it seems to me that we more and more expect a city to give the same show to every man. Where there is a difference in cost, as there is between the small and large user, we may admit it, so far as making a higher rate to residences than to large users; but a business man competes with his neighbor; he does not compete with the residents, he does not compete with the householders, but a large hotel is competing with a smaller hotel, a large store is competing with a smaller one, a large factory with the smaller factory, and it violates my theory of the function of government to give a special rate in such case, any more than the

government gives a special rate to those who buy a large amount of stamps, whether it be for postal purposes or for internal revenue purposes. The government does not do that in any country; nor in taxes do we make a special discount to a large taxpayer.

Yet I can see how there may be cases, in a small town, where there is some one consumer, like a railroad, perhaps, that uses a very large quantity of water, with no rival in that line of business in the town at all, and where if it had to pay as high a rate as does the ordinary business it would find it to its profit to pump an inferior grade of water, perhaps, from some nearby stream. And I can conceive the propriety in such a case as that of a reduced rate, if the water works feels that it is still a profitable contract and better than not to have the business at all. I think that is to be avoided if it is possible, and I am only speaking of a possible exception where a town wishes the revenue, and cannot get it at all from such a large consumer unless it makes a further third rate, we will say, or a third step in the gradation for such a class of users. But I wouldn't do it then, I had rather lose the consumer, if it means discriminating against some rival in the same line of business. It strikes me that we cannot do that in a municipal plant, and I do not think we would have to do it. I think we can accomplish what we are after by having a minimum, and then, perhaps, having two gradations in our rates.

Mr. W. C. Hawley.* Mr. President, I do not understand why a municipality should do its business any differently than a private corporation. As I understand the matter, furnishing water is not a municipal or governmental function, such as police protection, fire protection, or building streets. At any rate, in some states it has been decided by the courts that when a municipality enters upon the business of selling water, it does so on exactly the same basis as any private corporation. That being the case, it seems to me that the principle of wholesale and retail ought to enter into its business.

It is a difficult proposition to establish a schedule of rates along the lines which have been pointed out or suggested, and incorporate in it that principle of wholesale and retail business without

* General Superintendent, Pennsylvania Water Company, Wilkinsburg, Penn.

inflicting a hardship upon some portion of the consumers. It seems to me that it could better be done by taking into consideration those costs of furnishing water, such as interest, depreciation, sinking fund, maintenance, — taxes in the case of a private corporation, — and general expenses, such as salaries, office expenses, meter reading, etc., which have nothing to do with the quantity of water furnished, and dividing those costs among the consumers. Probably the best unit in that case would be the unit of family. Of course you have got to include the business houses, etc., and there will be some difficulties in arriving at an exactly equitable division, but some basis can be found by which those costs which bear no relation to the cost of furnishing water, that is, the pumping of so many gallons, can be divided accurately among the consumers, and thus a minimum rate fixed. Then take the cost of furnishing the water, pumping, filtering, etc., and fix that at a reasonable price, and let that water be sold in addition to the minimum rate which has been established by dividing the other costs among the consumers. In that way the benefits of the plant will be conferred upon all at equal rates, and a large user of water will get his supply at a somewhat lower price than the small user. In other words, the principle of wholesale and retail will obtain.

I am glad to see that the writer of the paper speaks of dividing the cost of the plant, and, in arriving at the cost of water furnished, includes only that portion of the plant which is not necessary for fire protection. It seems to me that there is a line which we water-works men must draw and emphasize, until the public at large is educated to the difference between the expense of furnishing water, — so many thousand gallons, — and the expense of furnishing fire protection. A company with which I am connected has recently had a case which has gone through the Supreme Court of Pennsylvania on that very point. The question came up as to what was a reasonable rate for fire protection. We called in experts and we designed a plant covering exactly the same ground as the plant in question, but to supply domestic and manufacturing use only. Fortunately there was very little manufacturing involved in that case. We took the fair value of the plant as it stood, and deducted from it the cost of a plant

for domestic and manufacturing service only, and the difference we maintained was the cost of furnishing fire protection, and that on that cost we were entitled to a reasonable return.

The lower court, after a most ridiculous hearing of the case, apparently decided arbitrarily, without any reasoning whatever, that a certain amount, less than half what we asked for, less than half what we showed we were equitably entitled to, was a reasonable amount. The case went to the Supreme Court of the State of Pennsylvania, which honorable body at the same sitting was able to determine that a two-cent rate per mile for passenger service was not a reasonable return upon the money invested by a railroad for passenger service, but could not see the difference between a 6-inch pipe to furnish fire protection and a 1½-inch pipe, which would be plenty large enough, to supply domestic use. That question will be fought out later. It is a question of vital importance to private water companies, and I think as a matter of good bookkeeping and a just and equitable division of costs, it is a matter of great importance to municipal plants as well, and I am glad that it is emphasized in this paper. I hope that others will have occasion to bring that point to the front, so that the general public will become educated.

Mr. Arthur A. Reimer.* One point on which the writer of the paper touched introduces a question which has been considered somewhat in our city, and I should like to know what the experience of the members is upon it, and that is the question of making one or several charges against several properties under one management or one ownership. That has become quite a live subject with us within the past few weeks. Our plan up to this time has been to make a separate charge for each separate connection, but one party is belaboring us now pretty strongly because we are doing that, and wants us to make one charge on his various properties. I was wondering if any of you have been confronted with such a proposition, and what your solution of the question has been.

Mr. Hawley. Put a meter in each property and charge for each property supplied.

* Superintendent of Water Works, East Orange, N. J.

MR. HUGH McLEAN.* This meter question I see, gentlemen, is always with us.

About four or five years ago, when the matter was discussed at length in Boston, practically the same questions came up. At that time I represented the city of Holyoke, and described the adoption of a flat meter rate, that is, water to be sold to all consumers at the same price. One of my reasons for it at that time was that the plan then proposed ought to cure the evil that the last speaker has referred to. The tendency of the times then was for consolidation of interests, and the tendency of the times to-day is the same. By a consolidation of interests, using so much more water, these interests got their water cheaper, thereby lessening the revenue of the department. For instance, at that time we sold water per quarter, I think it was at the rate of 15 cents per 1 000 gallons for the first 50 000 gallons; for all over and above 50 000 up to 200 000 gallons the rate was 10 cents a 1 000 gallons, and for all over and above 200 000 gallons the rate was 5 cents per 1 000. So by the consolidating of interests, such as four or five or as many as twenty concerns joining together under one management, the loss to the department of the benefit in revenue of the maximum rates as charged to each individual concern was equivalent to about $3 000 per year.

There was nothing to prevent the consolidation of other interests, which would lose to the department more of its revenue. I cited at that time, I think, the possible consolidation of the large department stores, whereby inside of each store the elevators might be operated by the elevator company. I suggested the possible consolidation of the landlords' association or the saloon-keepers' association, which could be accomplished just as well as in the case of two of the large industries which I cited as having consolidated.

That situation confronting us, it seemed to me that the claims of many of the citizens that they were entitled to the same rate, they being equal shareholders in the water department with the other taxpayers, had a good deal of justice, and we set out to change the rates and make one uniform rate. As I stated to begin with, the rate, I think, was 15 cents, 10 cents, and 5 cents.

* Water Commissioner, Holyoke, Mass.

We prepared tables showing what the loss of revenue would be under different ratings. With our engineer and our registrar and superintendent, we finally agreed on a flat uniform rate of $5\frac{2}{3}$ cents per 1 000 gallons, raising it two thirds of a cent above our lowest rate. That increased the rates, I think, to three or four consumers in the entire city, and reduced them to the balance. Our revenue was decreased, however, but slightly, and the system of having one flat uniform rate, the same to all, is working in a very satisfactory manner.

A further result has been in encouraging the introduction of meters, because those who wish to put in meters can buy all of their water at the flat rate; that is very evident. It is working along the lines of decreasing the per capita consumption, as more meters are being installed, and, as I have reason to know, it is lessening our expense for extensions by decreasing the consumption. It is paving the way for a filtration system, whereby we can lay aside some of our surplus to perfect the quality of the water supplied, instead of using it in extensions.

What was said a few minutes ago by Professor Bemis, that it was an injustice either for a public or private water corporation to have different rates, appealed to me. The United States government, as he cited, and as I cited at one of the meetings in Boston some years ago, sells stamps to Wanamaker the same as it does to me. If Wanamaker buys $10 000 worth of stamps, he pays at the same rate that you and I pay. The United States government's tariff is the same on small and large importations. Why should the small user of water have to pay three or four times as much for water as the larger user? I think it is an injustice, and I think we have solved the problem in Holyoke by making a flat rate and placing a rental on the meter. We put the meter into the applicant's premises free, and we charge him a percentage on it which is about 10 per cent., with a minimum of $2.00 per year, or 50 cents a quarter.

Mr. Allen Hazen. Do you charge for the use of the meter in addition to the five cents per 1 000 gallons, or does that cover everything?

Mr. McLean. We charge rental on the meter as already explained.

Mr. Hazen. It seems to me that they are on the right track in Holyoke, Mr. President.

The President. I have thought so for some time, Mr. Hazen.

Mr. McLean. The minimum charge is the same to all using the same size of meter. If a mill wants a large meter, which costs a lot of money, we charge them in proportion, — ten per cent. Ten per cent. is our rate for rental, and we keep in repair and renew the meters.

Mr. J. H. Child. There is one element of service from which, in the way the thing has worked out with us, we are getting no revenue, but from which we should get a revenue, in installing meters. We have a small system and have begun to install meters, first, on the factories and for the large consumers. The practical result of that has been that as soon as we placed the meters, — they had previously paid a flat rate which covered every use of water, the sprinkler heads, and private water hydrants, — the bills went up, in spite of the fact that some time ago we adopted a sliding scale, and some of them got their water for a very low figure. Then they started to drilling wells and eventually cut out almost the entire consumption of water from the water works. They have got an actual money return in their lower insurance rates because of the fact that they have water on their sprinklers at about 140 pounds pressure all the time. Now how to get a proper return for the service is a thing which has been puzzling us. We have in mind a charge of so much per head for the sprinklers, and a lump sum for each hydrant, that charge not to be operative if they use water to an amount that would exceed the minimum charge. I should like to know if that has ever been worked successfully in any other place.

Mr. McLean. I will state. Mr, President, what I forgot to say when I was on my feet before, that in our city we have a flat charge of $8 a year for hydrants, which the city pays. We charge that as a rental to the fire department for the use of water. We sell water to all of the public buildings the same as we do to individuals, *and we pay taxes to the city* the same as any private corporation. We paid last year $22 000 of taxes into the treasury of the city of Holyoke, which is the equivalent of the levy at the

regular tax-rate on the valuation of our plant. That in my opinion is the proper application of municipal ownership.

THE PRESIDENT. In answer to Mr. Child I should like to state that this question has been pretty thoroughly gone over in this Association in years gone by, and I do not think that as yet any satisfactory solution has ever been arrived at; I never heard of any. At one time a committee was appointed by our Association, including insurance men in its membership, and the committee presented two reports.

MR. CHILD. One of my commissioners is a manufacturer, connected with one of the large plants, and he has told me how the thing works out. One concern, after sprinklers were installed, got a reduction of its insurance from $850 to about $150 a year, the entire cost of the installation of sprinklers being paid for in two years. They are getting the profit of that, and we are getting almost nothing.

MR. ALBERT BLAUVELT.* Mr. President, the subject of how to regulate charges for private fire services, as you know, has been pretty well threshed over, but it may be profitable to take a moment's time to point out why it is that no rule can be devised except to size up the commercial needs of each individual case. A party installing a sprinkler equipment is under no necessity to use the public water system. It does not make any difference where he is located, whether he is in the middle of a prairie or in a town.

Under the rules of the National Fire Protection Association, — which association includes in its membership all classes of insurance bodies, and I am glad to say now includes a great many organizations which are not insurance organizations, and hopes to include water works associations in due time, — a party installing a sprinkler equipment for his private fire protection has two sources of water supply. You can always find out in an individual case what it will cost the plant to put in its second source of supply. That will depend entirely on the magnitude of the plant and the circumstances in connection with the plant. In some cases, perticularly in the West, a second source of water supply can be installed to entirely dispense with the public water service for com-

* Assistant Manager, Western Factory Association, Chicago, Ill.

paratively little money. In some small plants an air-pressure tank can be used, and the entire installation will not cost more than $800 or $900. In some other cases it would be necessary, perhaps, for the party to put in a large water tower or an elevated tank, or he might have to put in a big cistern or reservoir and an underwriters' pump, so that the expense of replacing the city water might run up to $7 500. In a rough way you can say that to dispense with city water for an ordinary protected plant will cost from $1 500 to $3 000, although it might come to only half of that or might come to several times as much. Now, interest, depreciation, and up-keep of that second source of supply, whatever it may be, will always be somewhere between 15 and 20 per cent. The parties owning the property, perhaps, will not admit it, but you all know very well that interest and depreciation and up-keep of any kind of apparatus will never be less than 15 per cent., and in some cases it will be more than 20. So if your party is up against a problem of spending $2 500 to dispense with city water altogether, you can figure that he can afford to pay you somewhere between 15 and 20 per cent. on that amount rather than to put in his private equipment. You will not find any of these plant owners who will admit that the saving in the cost of insurance has anything to do with the case. It is purely a matter of the investment necessary and the amount of the fixed charges which must be met in order to do without the public water works' service, which again can be done in any and all instances.

THE PRESIDENT. I should like to ask Mr. McLean at what size of meter he draws the line for his minimum charge of $2; that is, what is the smallest.

MR. McLEAN. Three quarters of an inch.

THE PRESIDENT. From that upward do you charge rental at the rate of 10 per cent.?

MR. McLEAN. Ten per cent.

MR. LEONARD METCALF.* I have been exceedingly interested in listening to the paper and to the discussion which has followed it, particularly to that suggestion of Mr. Richards that the cost of the fire service should be deducted from the cost of the entire

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

service before determining the rates, for it has seemed to me that the tendency to-day in our American cities has been rather in the opposite direction than in the direction of making payment to the water department which should in any way approximate the cost of furnishing hydrant service. I have looked into the question in a few cases, and I never have found a case in which the hydrant rental approached the actual cost of furnishing that service. It seems to me that in the case of Holyoke, for instance, $8 per hydrant cannot cover the cost to the water department for furnishing that service; so I was going to ask the speaker whether the rate of $8 per hydrant was based upon a computation of the cost of furnishing hydrant service; and I would also ask Professor Bemis what their present method of taking care of this matter in Cleveland is.

MR. McLEAN. The cost of $8 a hydrant was settled upon between the city and the water department when the agreement to pay the tax rate, that I have referred to, was made. That was before I came on the board. Our engineer, who is here, was a party to that agreement. Previous to that conditions were different; we did not pay any taxes, and we charged the departments a certain amount per year and didn't meter the water. The rate of $8 a hydrant I think was based on something near the cost of installing the hydrants. The agreement was entered into between the city and the water department in consideration of the latter paying a tax, and the former paying for all water used, the same as all other corporations, and the city to pay $8 a year for every hydrant as they were added.

MR. METCALF. That is, you are in effect putting upon the water taker the cost of furnishing the hydrant service, that is, the cost in excess of the amount which you are paid?

MR. McLEAN. I don't know as it is in excess. As I say, Mr. Tighe can answer that question; the matter was agreed to before I was on the board.

MR. JAMES L. TIGHE.* It was estimated to be the interest on the cost of the hydrant and the cost of installing it, and does not include anything for the water service.

* City Engineer, Holyoke, Mass.

PROFESSOR BEMIS. In answering the question which was asked with regard to Cleveland, I would say that some of our states suffer very much from the failure of home rule; we are not allowed to do as we would like by reason of state legislation, and this is true in regard to this particular point. The state law of Ohio absolutely prohibits any municipal water works from charging a cent for any water used for fire protection, public schools, hospitals, or charities. I do not exactly understand what led to the passage of the law, which is quite old, but it prevents our taking any action. However, we have done one or two things in Cleveland which have helped us some. We have metered the hospitals, and schools, and public buildings, and an agreement has been entered into under which it has been left to a prominent judge to arbitrate the question whether we haven't a right to charge for an excessive use in the schools and hospitals and charitable institutions, — that is, whether the state law contemplated an unreasonable use, or contemplated the use of water as a substitute for coal; for instance, in the running of elevators and fans, and for the manufacture of ice in the hospitals. All those uses of water are being enjoyed by the various institutions. And we are hoping, if we get a favorable ruling as to what is "reasonable use," to make the school department pay for any excess over that reasonable use per capita for every child in daily attendance. At the present time the use of water varies from 3 or 4 gallons per day per child in average attendance during the days the schools are in session to 50 gallons per day per child in average attendance. It is less now than it was before we put on meters.

We meet the question of fire protection by having a rate varying according to the size of the service. Parties are not allowed to use water for fire protection unless it is metered, or unless they pay a charge according to the size of the service. That is working very satisfactorily, and has met the approval of the fire underwriters.

THE PRESIDENT. It may be interesting to the members to know that in the city I represent * we are allowed to charge $25 a year for the rental of hydrants on our books, but they do not

* Springfield, Mass.

pay us any money. We are also allowed to furnish the schools and all public buildings, and water for flushing the sewers and watering the streets free. We have that privilege. We get no money whatever out of the municipality. We hope that sometime all that will be changed.

MR. McLEAN. Do you pay taxes?

THE PRESIDENT. We do not pay any taxes. I think we would prefer to have the same arrangement that they have in Holyoke.

MR. McLEAN. I should like to ask Professor Bemis if in his opinion it is not the fairest way to meter all the water for the schools and for the different departments and have them pay, the same as other individuals and large users of water, and then have the water department pay a tax, the same as other corporations?

PROFESSOR BEMIS. I believe in that most thoroughly. It is not simply taking the money out of one pocket and putting it into the other, but it makes each department more careful of its own expenditures and own wastes. For instance, if each department at Washington had to pay the post office department for its use of the mails, it would be far more careful of waste, even though it all comes out of the government treasury in the end. But if you cannot do that, if the law does not permit that, I think every water-works department should establish a system of bookkeeping and publish to the community every year just what each public building and each department costs to the water department. You can often get a very considerable reduction in waste, after you have metered the water, by presenting the matter in a tactful way to those in charge. For example, we have succeeded in having all the public fountains closed at night; before we had meters they were kept running night and day. We found that when there was free use of water in the cemeteries, in our best cemeteries there was more water being used per capita than the same number of people used when living. [Laughter.]

MR. FRANK L. FULLER.* I will say just a word, Mr. President, in regard to the arrangement at Wellesley, Mass. There we consider the meters as a part of the water-works plant, and we have

*Civil Engineer, Boston, Mass., and member of Water Board, Wellesley, Mass.

a minimum rate of $6 which entitles the consumer to 16 000 gallons per year, at the rate of 37½ cents per 1 000 gallons. If they use in excess of that amount the price is $0.25 for the excess. We charge every one the same price, which I think is right. I always have thought that families should not be called upon to pay a higher price for their water, which is an absolute necessity to them, than is paid by those who use water for profit. A good many greenhouse people have thought that they should have water at a less rate, but the rate has always been maintained at the same price for everybody, and I think it gives general satisfaction. The town makes an appropriation for water used in the street sprinkling and for that used in fountains and for the hydrants. The water used in the public buildings is also metered. We do not meter the water used in street sprinkling, but there is an account kept with that by the number of loads of water put upon the streets.

I should like to say just a word in regard to the question which has been raised about the payment of water rates by the landlord. Of course our town is different, I suppose, from the case Mr. Richards spoke about in his paper. We always send the bill to the tenant, and the tenant pays the water rates, the same as he pays his other bills. The landlord has nothing to do with it. I suppose, perhaps, the landlord might be responsible for the water rates, but we have never had a case where the tenant didn't pay. As I remember it, we have only a few cases where one meter would cover several families, and we have endeavored to arrange it so that each tenant has his own meter and is charged for the water he uses the same as any one else.

Mr. H. N. Parker.* I have recently had the pleasure of visiting most of the public water works systems in the state of Kansas, and I was very much surprised to find how generally meters are used throughout the state. As we all know, here in the East the introduction of meters has met with a good deal of opposition, but there it seems to be taken for granted that it is a just and equitable way to sell water, and the town is the exception, I think, which sells water in any other way than by meter. They

*Assistant Hydrographer, United States Geological Survey, Washington, D. C.

have different ways of selling it, but the use of meters is practically universal, and it is only a question of time before all the towns in Kansas will be completely metered.

Mr. W. H. Richards (*by letter*). It is a matter of satisfaction to know that there was no endeavor to controvert the logic of my statements that the only equitable way to sell water is by measure; that the reason for the introduction of meters is equity between customers, and that the charge for water should be based on the cost of supplying the same to the particular party under consideration.

If it costs less to supply a large quantity than a small quantity, then the rate should be less for a large quantity. If a large quantity is drawn through one service pipe, then it costs less. In the case of fire hydrants the quantity of water is comparatively so small as to be negligible, and the cost is in the hydrants and the extra large pipes through which the water is drawn, and they should be so charged for. The same holds good for private fire service.

I agree with Mr. Hawley that a municipal water works stands on the same footing as a private corporation, and further, that the taxpayer has no interest in the water department except in so far as the municipality uses water; and every public use should be paid for on the same terms as a private use.

If, as I understand was the case at Holyoke, all the water used through many different service pipes was grouped together and charged on one bill, then the cost of the service pipes and mains to furnish the supply was neglected, and the reason for a graduated rate was circumvented. If the rules had required the charge to be based on the quantity drawn through *each* service pipe, then the laws of logic and equity would have been satisfied. If the Holyoke water department can supply water at $5\frac{2}{3}$ cents per thousand gallons it has built its system at a very low cost. If it is supplying water in very large quantities to manufactories at the same cost as to residences, it is charging a larger proportion of the cost to one than to the other.

The illustration of the charge for postage is an argument in favor of graduated rates, since the charge for other than first-class matter is less because the service is less valuable, just as water is

less valuable to the manufacturer than to the party using it for domestic purposes.

In reply to Mr. Fuller, it goes without saying that to prevent loss, the water rent should be a lien on the property, and hence the owner is liable; otherwise there is no way of collecting the water rates except by a suit at law for debt, and if two tenants are supplied through one service pipe, to shut off the one who will not pay, necessitates shutting off the one who has paid.

RUBBER PIPE JOINTS.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON, MASS.

[*Read September 24, 1908.*]

During the past winter in Europe the writer noticed that much water pipe was being jointed with pure rubber rings in place of the customary lead and yard. It is thought that this simple process might be of interest and use to the members of this Association. The process was very simple. The rubber ring was slipped over the spigot end of the pipe, the spigot of this pipe was then forced into the bell of the next pipe by means of a long lever, compressing the rubber between the iron surfaces and making a very tight joint. Clay was then forced into the remaining space and the job was done.

The following information was obtained regarding this method of jointing. To begin with, the "Normal" pipe of the *Verein deutscher Ingenieure* has the form shown in the following sketch (Fig. 1).

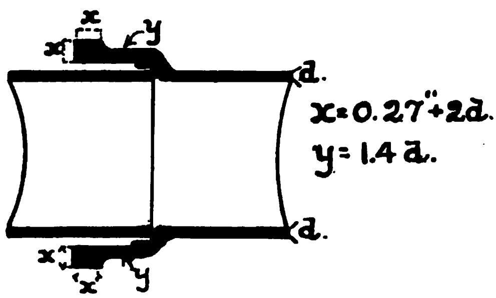


FIG. 1. "NORMAL" CAST-IRON PIPE OF THE VEREIN DEUTSCHER INGENIEURE.

The thickness of the shell of this normal pipe is determined by the formula

$$d = 6.0 + 0.001 \times D \times A = \text{thickness in millimeters.}$$

where

D = inside diameter in millimeters.

A = testing pressure of 20 atmospheres.

The German pipe is made in more sizes than is customary in this country. A few of the dimensions of the "Normal" pipe corresponding to the standard New England Water Works Association pipe diameters, and expressed in equivalent United States units of measure, are given in the following table:

SIZES OF GERMAN "NORMAL" PIPE.

Inside Diameter. Inches.	Inside Diameter. Millimeters.	Outside Diameter, Inches.	Laid Length, Feet.	Diameter of Sockets, Inches.	Depth of Sockets, Inches.	Width of Joint Space, Inches.
4	100	4.65	9.9	5.24	3.46	0.30
6	150	6.69	9.9	7.28	3.70	0.30
8	200	8.75	9.9	9.37	3.94	0.32
10	250	10.78	11.1	11.44	4.05	0.33
12	300	12.82	13.1	13.10	4.13	0.33
14	350	14.88	13.1	15.53	4.21	0.33
16	400	16.89	13.1	17.64	4.33	0.37
18	450	18.90	13.1	19.63	4.41	0.37
20	500	20.93	13.1	21.73	4.53	0.39
24	600	24.97	13.1	25.78	4.72	0.41
30	750	31.10	13.1	31.98	5.00	0.43
36	900	37.20	13.1	38.18	5.31	0.49
48	1,200	49.40	13.1	50.52	5.90	0.51

It will be noted that the "Normal" pipe differs in many particulars from the New England Water Works Association "Standard" pipe, e.g.:

First, there is neither bead on the end of the spigot nor retention spaces for the lead in the bell.

Second, the socket is deeper and there is a shoulder in the bell which serves the purpose of the bead on the New England Water Works Association standard pipe.

Third, the increases in dimensions of socket vary more uniformly with the increase in diameter of the pipe.

Fourth, should the shell of the pipe be thickened, the outside diameter remains constant.

In thickness of shell, the German pipe lies between classes A and B of the New England Water Works Association standards, as the following table will show:

THICKNESS OF PIPES.

"NORMAL" PIPE OF THE VEREIN DEUTSCHER INGENIEURE COMPARED WITH STANDARD PIPE OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Diameter.		Thickness of Shell. Inches.			
Inches.	Millimeters.	Ver. d. Ing.	N. E. W. W. Assn. Class A.	Class B.	Class C.
4	100	0.35	0.34	....	0.36
6	150	0.39	0.38	....	0.42
8	200	0.43	0.42	....	0.48
10	250	0.47	0.47	0.50	....
12	300	0.51	0.49	0.53	....
14	350	0.55	0.53	0.57	....
16	400	0.57	0.55	0.60	....
18	450	0.59	0.57	0.63	....
20	500	0.63	0.60	0.66	....
24	600	0.67	0.64	0.72	....
30	750	0.79	0.71	0.81	....
36	900	0.89	....	0.90	....

The German pipe is recommended for general use with pressures varying from 60 to 105 pounds per square inch.

Pipe for use with rubber rings should not have the retention space cast in the bell, and the spigot may have a groove 0.2 inch deep to prevent the ring slipping during process of jointing. This groove is sometimes omitted. The pressure which the joint will withstand depends upon the degree of compression, and consequently the holding friction of the rubber ring. The groove permits a thicker ring to be used than is possible without it.

The following sketch (Fig. 2) shows how "Standard" pipe may be adapted for use with rubber rings, and the degree of compression

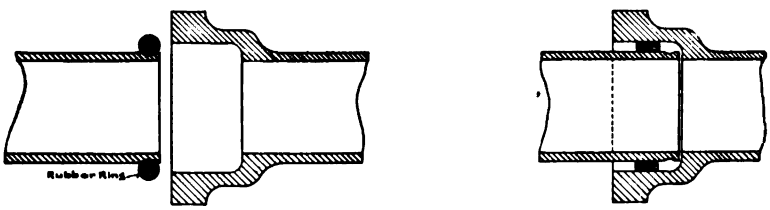


FIG. 2. METHOD OF JOINTING PIPES.

to which the ring would be subjected in practice. The thickness of the ring before compression should be twice the width of the joint. The inside diameter of the rings should be somewhat less than the outside diameter of the pipe, that they may be held in place by their own elasticity during the processes of jointing.

The sizes of the rings for pipes of classes A, B, and C would be as follows:

Diameter of Pipe, Inches	Inside Diameter of Ring, Inches.	Thickness of Ring, Inches.	Weight of Ring, Lbs.
4	4.50	0.80	0.136
6	6.50	0.80	0.195
8	8.50	0.80	0.247
10	10.25	0.80	0.294
12	12.25	0.80	0.348
14	14.25	0.80	0.401
16	16.25	1.00	1.437
18	18.00	1.00	1.582
20	20.00	1.00	1.747
24	24.00	1.00	2.081
30	30.00	1.00	2.45
36	36.00	1.00	3.08

The rubber rings used should be of the best pure gum, preferably the variety known as Para gum. They cost from $2.50 to $3 a pound at present prices, and are usually made of pure gum rods, butt-jointed and vulcanized. Their cross section is circular. Rings of hemp coated with rubber have been tried but are not to be recommended because of their low elasticity, upon which the tightness of the joint depends.

The comparative costs per joint of lead and rubber joints may be estimated as follows, assuming lead to cost 5 cents and rubber $3 a pound, and using New England Water Works Association Standard pipe without the retention space:

COMPARATIVE COSTS OF LEAD AND RUBBER PIPE JOINTS.

Diameter of Pipe, In.	Thickness of Joint, In.	Estimated Cost of Lead, Yarn, and Calking.	Cost of Rubber Ring.	Cost of Laying.	Total Cost per Joint. Lead.	Total Cost per Joint. Rubber.
4	0.40	$0.54	$0.48	$0.09	$0.63	$0.57
6	0.40	0.86	0.58	0.12	0.98	0.70
8	0.40	0.97	0.74	0.15	1.12	0.89
10	0.40	1.21	0.88	0.20	1.41	1.08
12	0.40	1.48	1.05	0.24	1.72	1.29
14	0.40	1.78	1.20	0.30	2.08	1.50
16	0.50	2.08	4.31	0.36	2.44	4.67
18	0.50	2.39	4.75	0.42	2.81	5.17
20	0.50	2.68	5.24	0.48	3.16	5.72
24	0.50	3.60	6.25	0.60	4.20	6.85
30	0.50	5.30	7.34	0.90	6.20	8.24
36	0.50	6.51	9.24	1.17	7.68	10.41

It will be noted that up to and including 14-inch pipe the rubber joint is a little cheaper, even without allowing for the cost of bell-holes not needed for jointing with rubber rings. There is no reason why the width of joint for pipe 16 inches in diameter and above could not be reduced to 0.45 inch, or even 0.40 inch, when the cost of rubber joints would be less than that of lead joints, as shown in the following table:

COMPARATIVE COSTS OF LEAD AND RUBBER PIPE JOINTS FOR PIPE 16 INCHES AND OVER IN DIAMETER, HAVING A JOINT SPACE 0.40 INCHES WIDE.

Diameter of Pipe, Inches.	Cost of Joint. Lead.	Cost of Joint. Rubber.
16	$2.44	$1.89
18	2.81	2.11
20	3.16	2.31
24	4.20	2.82
30	6.20	3.56
36	7.68	4.13

The advantages and disadvantages of the rubber joint may be stated as follows:

One of its chief advantages is that it is extremely flexible. The rubber ring is midway in the bell and therefore at the axis of movement. Therefore no serious unequal compression of the ring can result if the pipe be thrown out of line. The joint is almost perfectly tight and needs no calking; it may, therefore, take the place of flanged pipe for suction mains connecting tube wells. In such cases the position of the branches may be adapted to suit the wells. This is often a great convenience because it is impracticable in all cases to sink wells in exact predetermined positions. Pipe with rubber joints is easier to lay on account of the absence of bell-holes and the simplicity of the jointing tools. There is less breakage of pipe due to settlement of earth. It resists electrolysis most efficiently. The rubber joint, on the other hand, has not been used for high pressures. How much pressure it will withstand could not be ascertained. It is in use in systems which carry 50 pounds pressure, and probably could be used for pressures considerably higher. The joints appear to be durable. If exposed to air, rubber absorbs oxygen, loses its elasticity, and becomes hard and useless. Compressed in a pipe joint, however, it

is preserved. A ring removed after eighteen years of service was apparently as good as new. It would be more durable in contact with ground water than with surface water.

Many German and European supplies are from wells driven in gathering grounds located above the level of the city. In several instances the water is siphoned from the wells to the distributing reservoir by means of rubber-jointed pipe. The proposed new water supply of Prague contemplates such a line from the mountains several miles distant from the city.

This paper is written with the hope that some members of this Association may try these joints and determine their worth under the conditions of American water-works practice. While not at all new, they have not been tried in this country to any great extent. The writer wishes to thank Dr. A. Thiem, C. E., and Mr. A. Lang, C. E., of Leipsic, for information regarding the use of this joint.

DISCUSSION.

The President. Gentlemen, the paper is now open for discussion.

Mr. Allen Hazen.* Mr. President, I had the good fortune to see these joints in use in Germany about fifteen years ago. I think the joints were comparatively novel at the time, and if I remember, in speaking to this Association after my return, I mentioned them. They were used at that time in suction mains. They were used because by their use it was possible to get a line which was perfectly air-tight, and a lead joint, as you know, cannot be maintained air-tight. I gather from what Mr. Weston says that their use has been extended, and the extension certainly is a very interesting fact.

I wonder if Mr. Weston knows if in France and Belgium joints have been made partly of rubber and partly of lead, with the idea of combining some of the advantages of both materials.

Mr. Weston. I haven't heard of joints being made of rubber and lead, but I have heard of joints being made of hemp rings coated with rubber, with lead poured on top. A rubber compound ring, which is very similar to our pipe joint packing, is more water-tight than yarn, of course.

* Consulting Engineer, New York City.

MR. MURRAY FORBES.* In case one of those joints should give out, how are the repairs made? Do they have to pull the pipe apart again?

MR. WESTON. Yes. It is doubtful if rubber joints are practicable where frequent repairs or changes are to be made.

PROF. E. W. BEMIS.† Isn't the Standard Oil Company using the Dresser coupling for high pressures of natural gas?

MR. WESTON. I cannot say.

PROFESSOR BEMIS. They are using it for their distributing system entirely in many cities of the West where the pressures are not as large as 60, — and are down to 40 pounds in some cases, — but I think they are using them in their mains running up from West Virginia where they have 300 to 400 pounds pressure. It is not exactly the same thing, but it is a rubber coupling called the Dresser coupling. I haven't examined it very carefully, but it is on the same principle.

MR. W. C. HAWLEY.‡ I might answer the question by saying that there are a great many Dresser couplings used in western Pennsylvania under pressures up to 400 or 500 pounds per square inch for natural gas.

In connection with the matter of pipe joints it may be of interest to members of the Association if I call their attention to a new material, which has come on to the market within two or three years, known as "Leadite," manufactured in Philadelphia. My attention was called to it by a salesman of water-works supplies some two or three years ago, and on his advice I got some of the material and tried it, and I have been using it exclusively now for over two years. It is a mixture of iron filings, sulphur, and silica. It melts at a temperaure considerably lower than lead,— at something like 250° F., I think,—and is poured into the joint in the same way as you pour lead, but it requires no calking. It weighs about one sixth as much as lead and costs about twice as much per pound; therefore per unit of volume it costs one third. The cost of a large bell hole is saved, and the cost of calking, and I believe my joints are costing me from a third to perhaps a half of what lead joints

* General Manager, Westmoreland Water Co., Greensburg, Penn.
† Superintendent of Water Works, Cleveland, Ohio.
‡ General Manager, Pennsylvania Water Co., Wilkinsburg, Penn.

would cost. The material cools quickly with little shrinkage. I have had no trouble with the shrinkage except in some large 30-inch sleeve joints. Repairs are easily made. The material is rather brittle when it is hard, and with a chisel is easily cut out, and you can run the new part of the joint and it takes a firm hold on the old part; the material seems to take hold of the iron when it is clean. I am using it under pressures up to 200 pounds per square inch, and have had no trouble with any of the joints except where we had a slip on the hillside the other day which took pipe and all, and there a little of the leadite crushed out, where I suppose the whole joint would have gone if it had been lead.

It requires rather careful manipulation, and yet our men have had no difficulty with it. Our man who melts it is an eighteen-year-old Italian, and he thinks there is nothing like leadite now. I understand it is in use in Atlantic City, and I presume Mr. Van Gilder can tell us something about it. A contractor recently told me that he had been laying some 12- and 16-inch pipe through a swamp near Reading, Penn., I believe, and he had found leadite very much better for use in wet ditches than lead; he simply left a hole at the bottom of the joint with the water running out of it and poured the hot stuff in and it closed up the joint, making it tight with very little difficulty. The worst trouble we have had is on account of its catching fire if it gets a little too hot, but it is very easy to put the fire out by throwing a few handfuls of the fresh material on, — it comes in the form of a fine black powder, — and my foreman recently told me he found that a bucket of water would put it out quickly without any serious consequences.

THE PRESIDENT. Is Mr Van Gilder in the room?

MR. VAN GILDER.* I do not think I can say anything further as to the use of leadite, except to indorse most heartily what Mr. Hawley has said. We have had no difficulty with it except with one joint, during the two years and a half I have been in this department, and that was in a soft bed under the railroad with very heavy traffic. That is a case where it was impossible to hold a lead joint, and it was impossible to hold a leadite joint because in time it would crumble. We have overcome that since by putting a sleeve over the pipe. We find it to be very superior to lead

* Superintendent of Water Works, Atlantic City, N. J.

in very wet places, for the reason you can pour it in the joint with perfect safety to your men, which would be utterly impossible with lead. We can fill up the joints by pouring in the material quickly, and then we let it chill and it is all done.

MR. HAWLEY. Of course one has to use a much higher " gate " with leadite than with lead, on account of the difference in weight. We make a hollow cylinder of clay, perhaps 6 or 8 inches high, put that over the bell, and pour through that, filling it, and leave it long enough to chill. I think a large joint should be run slowly because there is some shrinkage, just as there is with sulphur.

MR. CHARLES E. CHANDLER.* In connection with rubber joints and air-tight joints for pumping, I will say that there are several miles of cast-iron pipe laid in the city of Norwich, with rubber joints, for transmitting compressed air, which may be of some interest. All of the joints are rubber joints, formed by putting a sleeve over the joint, the pipes not having any bells. A rubber ring goes on each end of the sleeve, and outside of that a double clamp which bolts and squeezes the rubber and makes the joint. The rubber rings are square in section and the clamps are not quite square, so they hug the rubber bands down to the pipe. Those rubber joints can be made just as tight as screwing up the bolts will make them.

The experience there was that after about a year practically all the joints had to be dug up and the bolts tightened. After being in five years, under 90 pounds air pressure, there are a great many leaks. In the center of the city, where brick paving was laid last year, the circumstances are such as to show up the leaks more than ever before, and it is quite interesting to people who go by on the trolley cars. For instance, a leak in the compressed air main in an ordinary street, where there was no paving, unless it was raining, would not show up at all, but when the street was paved with brick the only escape for the air was near the trolley tracks, and when the trolley sprinkler goes along, and there is plenty of water, the pot boils very nicely, and it attracts a great deal of attention.

MR. FRANK L. FULLER. Was that wrought-iron pipe?

* Civil Engineer, Norwich, Conn.

MR. CHANDLER. No, sir; it was plain, straight cast-iron pipe without any bells.

MR. WESTON. I might say in connection with the experience that Mr. Chandler has had in Norwich that I think one would expect that any rubber joints in contact with air would become hard in about two years, or less. Rubber, even the best of rubber, will absorb about 25 per cent. of its weight of oxygen in a very short time when exposed to air, and when it does so it changes from what might be called a gum to a gum resin, just as linseed oil changes from an oil to resin, and in doing so becomes brittle and useless for all purposes where elasticity is of value. I think the cases in which we would think of using rubber joints, or the cases where they are particularly applicable, are those in which the rubber can be protected against the action of oxygen, as it can be in a water pipe, where the space on one side, the outside, would be filled with clay, and on the other by the silt which would come from a surface water and protect the joint, and also on the inside by the carbonic acid gas which is always present in a ground water. I would not think that the rubber joints I have described would be applicable for use with air pipes, but I do think it can be used especially for suction pipes in connection with driven-well systems.

MR. E. S. SAUNDERS. Suppose you had a cracked end and had to cut off the end of a bead end, how would you hold the pipe?

MR. WESTON. I think it would be safer in that case to make a lead joint, or put the lead over the rubber, but in a long line of pipe I think it is perfectly safe to use rubber.

MR. CHANDLER. I suppose it might be proper to say that in France, where they use a great deal of compressed air, they use the rubber joints. Perhaps some one here can tell us whether those air pipes are laid in subways, where they are accessible for repairing the joints. I do not know whether that is the case, but the idea of using rubber joints for compressed air came from the fact that they are used in France. These joints I speak of, of course, have very slight contact with the air. We have the sleeve over the joint and the rubber on the outer end of the sleeve, and the opportunity for air to get to the joint is very slight, but of course it can get there.

MR. WESTON. As I remember, some European rubber joints are made with ordinary flanges and they require packing. I have seen very few cases however.

MR. CHANDLER. Flanged pipes?

MR. WESTON. Regular flanged pipes.

MR. CHANDLER. I didn't think so, but it may be so. The joint I speak of gives flexibility, which of course a flanged joint would not have.

MR. M. N. BAKER. Those interested in the use of leadite for pipe joints can find a considerable amount of further information on the subject in the proceedings of the American Water Works Association for the present year. The consensus of opinion on the part of those who spoke on this material, so far as I remember, was very favorable to it.

MR. WESTON. A recent letter from a German friend states that rubber rings are not being used in general practice for jointing pipes beneath paved streets or where pressures are very high. In such cases, lead and yarn joints are more economical. For work inside of buildings where pressures are high, rubber joints with the rings secured in place by means of an iron ring clamped to the pipe described by Mr. Chandler have been used in place of flanged joints, thereby gaining much flexibility. The new use which is being made of rubber joints is for long mains leading from wells or other gathering grounds across hills and valleys, under vacuum and pressure, to pumping stations or cities. In these cases the superior tightness of a rubber joint outweighs most disadvantages.

MR. WILL J. SANDO. (By letter.) The rubber ring joint has been used between faced flanges inserted in a wedge-shaped groove a great many years with good success.

The sketch by Mr. Weston shows that the rubber makes a parallel joint between the inside of the bell and the outside of the spigot, and the tightness is dependent on the friction of the rubber and metal. In this form it might be blown out by the pressure of the water inside of the pipe. This might easily cause trouble and be very expensive in repairs.

The accompanying sketch (Fig. 3) shows, I believe, a more reliable form of this same joint. It is made by tapering the outside of the spigot end so that the rubber ring will tighten more as it is

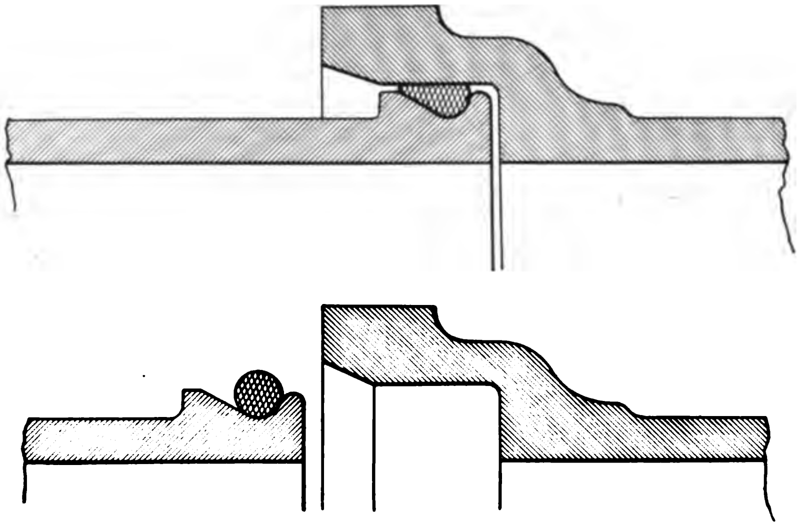


FIG. 8. RUBBER PIPE JOINT AS SUGGESTED BY WILL J. SANDO.

inserted into the bell end and then any additional pressure from the water inside will also tend to make the joint tighter. It seems to me there are places where a joint made in this manner could be used to good advantage.

INSURANCE RATES AND THE WATER SERVICE.

BY FRANK A. BARBOUR, CIVIL ENGINEER, BOSTON, MASS.

[Read September 24, 1908.]

Some recent work involving the betterment of the existing water works in several cities and towns, and the fact that, following these improvements, reductions in the insurance rates were granted by the underwriters, has suggested to the writer that a very brief description of the work done, in so far as it affected the fire service and a statement of the reductions allowed, might be of interest to this Association.

It may be possible that in some communities the logical results of such improvements have not been obtained — either through civic inertia or through failure to appreciate the opportunity, — and that the experiences herein described may prove profitably suggestive.

IMPROVEMENT OF ST. JOHN WATER SUPPLY.

In 1905, the development of a new water supply for the city of St. John, N. B., was undertaken, the work involving the extension of the then existing pipe lines from a point about 5 miles distant from the city to a more distant source, at an elevation 138 feet higher than the old supply. The pipe lines to the city included two 24-inch cast-iron pipes, one laid in 1857, the other in 1873, and a 12-inch cast-iron pipe laid in 1851. The distribution system, which was generally of equal or greater age (some of the pipes having been laid as early as 1837), was fairly adequate in size, requiring for efficient fire service additional pressure rather than enlargement of pipe diameters.

The extension of the works to the new supply included 10 000 feet of 33-inch wood stave pipe, 7 500 feet of 39-inch reinforced concrete conduit, laid about 20 feet below the hydraulic grade line and ending in a lake of 600 000 gallons capacity, but with small watershed, from which lake a 48-inch reinforced concrete conduit, 6 200 feet in length, laid partly in tunnel and partly in open cut, connected with the main source of supply, the Mispec

River where a concrete dam was constructed. The total expenditure (not including a pulp mill, purchased in order to avoid damages for diversion of water, which should yield an amount in rental equal to its cost), was about $300 000.

The topography of the city is most irregular, surface elevations varying as much as 125 feet, the higher areas being within 40 feet of the surface of the old supply. Previous to the installation of the new works the system had been divided into a high and low service, the water for the former being lifted by turbine and power pump 35 feet higher than the elevation possible by gravity. Under the present system the city is supplied in a single service, the pipes working in common with full pressure on the mains to the city limits, where two Ross regulating valves are installed by which the pressure is reduced some 15 pounds or to the point where it will drop by friction loss in the mains under an extreme fire draft. In this way the distribution system is relieved of the full static pressure without detriment to the fire service.

The application of the higher pressure to a system of such age was a matter of considerable responsibility and one demanding great care and patience. It was out of the question to undertake a general replacement of the system, as this was beyond the financial capacity of the city. The proof of the ability of the 24-inch mains to meet the new conditions could only be made by actual hydraulic tests in the ground. Examination of individual pipes, while indicating the iron to be of good quality and of the necessary thickness, was of relatively small value, as the breaks would occur in pipes weaker than the average. It was, therefore, decided, to supply the city through one of the 24-inch lines and to test the other main by gradually stepping up the pressure, repairing such breaks as occurred with each increment, and finally applying 20 pounds in excess of the full static pressure of the new supply by developing water-hammer through the operation of blow-off valves. After the weak pipes in the first main were eliminated in this way, this conduit was thrown into service and similar work done with the other main. The 12-inch pipe laid in 1851 was abandoned as of little or no value. When the full pressure of 110 pounds had been applied to both mains, the pressure in the distribution system was gradually increased by manipulating the regulating valves.

By the installation of these new works the pressure throughout the city was increased about 40 pounds, and from four to ten good direct fire streams, the number depending on the variation in surface levels, were made possible, while with engines from ten to twenty streams were obtained. As the commercial center is generally in the lower areas, the possibility of direct service is of great value, especially in a city where the efficiency of the fire department is not up to the metropolitan standard. With the old pipe lines, not more than two direct streams were possible and the maximum draft with engines was probably not more than 2 000 gallons per minute.

RESULTING SAVING IN INSURANCE.

As a result of these improvements a reduction in the insurance rate of 25 cents has been granted on mercantile property, the total yearly amount somewhat exceeding $30 000, which is more than double the interest cost of the entire improvements.

NOTES ON OLD PIPES AT ST. JOHN.

A few notes on the work in St. John in connection with the old pipe lines may be of interest. The pipes in the first 24-inch line, laid in 1857, have a thickness of about three quarters of an inch. The exterior surface shows no signs of having been coated; neither does it show any serious corrosion, the iron when broken being good to the extreme outer edge. About one sixteenth of an inch of the interior surface is black and easily abraded. The pipe is badly incrusted, although it has been cleaned several times in past years by the method used in St. John and Halifax, and already described in a paper read before this Association by the superintendent of the St. John system.* The joints were made of white pine and are in good condition, without leakage under the heavier pressure, except in some places where the key-wedges were badly fitted. A section of this pipe, 3 600 feet long, laid through marsh mud at tide level, was found to be badly disintegrated and was replaced. In many instances it was possible to cut the pipe with a knife through a considerable portion of its thickness. The new

* JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. XIII, p. 147 (December, 1898).

cast-iron pipe was embedded and wrapped with a layer of clay, since such sections of the old pipe as had been laid in this material have apparently escaped any disintegrating effect of the tidal mud. Pipe laid in sand at about the same level was not affected, and of twenty-one lengths, each 9 feet long and weighing 2 300 pounds per length, only one broke.

The pipe laid in 1873 was of two classes: one, seven eights of an inch thick, and the other one inch thick. The pipe was coated and is in better condition than the pipe laid at the earlier dates. In this line four types of joints were employed: first, a turned and bored joint; second, a turned and bored joint made up with lead and a strap to hold the lead in place; third, a wood-stave joint, and fourth the ordinary lead joint.

In the distribution system relatively few breaks have occurred, although in some cases the pressure is 95 pounds per square inch. The pipes which have been broken have usually been thin on one side, presumably the result of having been cast horizontally. The service pipe was not tapped but driven into the main, with a keeper which extends around the pipe. Local plumbers predicted that these connections would be blown out by the heavier pressure, but only one such case has occurred.

Precise instruments have not been available for the determination of the friction loss in those old mains, but from gage readings and measurements of the discharge by Venturi meters, it appears that the coefficient C in the Chezy formula, practically applicable to these mains, is between 65 and 70, the factor of leakage from the pipes between points of gaging discounting any attempt at greater accuracy.

The gradual stepping up of the pressure on the distribution system by the use of the regulating valves and measurements of the flow by Venturi meters indicated an increase in leakage from the distribution system about 5 per cent. greater than in direct ratio to the square root of the pressure. This leakage, while not of serious moment in the present instance where the supply is ample and obtained by gravity, would, in the case of a pumping system, be as great a factor in the depreciation of the old mains as the actual strength of the pipe. In an endeavor to determine the ocation of abnormal leakage the pipe system is being tested in small

districts between the hours of 12 midnight and 4 A.M. by shutting connections to the section under examination and supplying it with water through a meter set in a hose line stretched from a hydrant outside to a hydrant inside the district. Street after street is then shut off and the effect on the meter noted. Gates are sounded for leakage by the aquaphone, and as an additional check a small meter is placed on some sill-cock and water run through it for a certain length of time. If the water in hose line indicates an equal discharge it is concluded that all water entering the district is being measured. Leakage is an element of interest in insurance rating because of its effect in reducing pressures in the distribution system and may become of serious moment when large in proportion to the legitimate consumption.

IMPROVEMENT OF THE FREDERICTON WATER SUPPLY.

The city of Fredericton, N. B., was supplied by pumping direct into the mains without elevated storage, the pumps necessarily running twenty-four hours. In connection with the installation of a mechanical filtration plant recently constructed, a clear water well of 400 000 gallons capacity was provided, largely as a fire reserve, and the old pump of 1 500 gallons per minute capacity was reinforced by new apparatus of double this discharge. In time of fire a pressure of 80 pounds is maintained at the station, but the effective pressure at the hydrant is considerably less owing to an inadequate distribution system, twenty-four years old, and much incrusted by the action of the river water on the pipes.

RESULTING SAVING IN INSURANCE.

As a result of the installation of the larger pump a reduction in the insurance rate has been made equal in yearly total to about $6 000, or practically three times the interest on cost of the improvements chargeable to fire protection.

IMPROVEMENT OF THE ATTLEBORO WATER SUPPLY.

In Attleboro, Mass., previous to 1904, the principal elements of the distribution system were a single main between the pumping station and the town, and a steel standpipe of 660 000 gallons capacity, with its water surface, when full, 140 feet above the level

of the business center. This standpipe held the night's supply, but in case of fire, owing to inadequate elevation, it was shut off from the system by the closing of a gate and the pressure then obtained direct by starting up the pumps. Improvements carried out between 1904 and 1906 included the construction of a reinforced concrete standpipe of 1 500 000 gallons capacity, with its top 100 feet higher than that of the old standpipe; the laying of a second main between the pumping station and the point of storage, and of a larger main from this latter point to the center of consumption. Under the old system of direct pressure in time of fire the maximum service was six streams with 65 pounds at the hydrant. The new standpipe is of such capacity and height that assuming a sixteen-hour shut-down of the pumps, the storage reduced during this period by the estimated consumption twenty years hence and a fire occurring at the end of the sixteen hours, fifteen streams with 65 pounds at the hydrant can be maintained for one hour without starting up the pumps. In a test made in 1906, sixteen streams discharging 3 800 gallons per minute were shown with a pressure at the hydrant of 75 pounds. *As a result of these improvements a 10 per cent. reduction of the mercantile rate of insurance was allowed by the underwriters.*

GENERAL CONSIDERATIONS.

The three preceding instances of reduction in the insurance rates as a result of improvements of the water service illustrate the value accorded by the underwriters to increased pressure in a gravity system, greater pumping capacity in a direct pressure system, and larger storage and the duplication of mains in a pumping system with standpipe. The amounts of the reductions were determined by committees representing underwriting associations — in two cases as a result of applications made by the municipal authorities after the work was completed, and in this third case, that of St. John, N. B., as a reward promised before the improvements were undertaken. It is safe to say that in none of these cases was there any attempt to estimate the value of the improvements in reducing the fire hazard on any definite basis derived by experiences and made applicable by records of fire losses relative to the character of the water service. It would seem, however, that the

time must soon arrive when such logical proportioning of rates to the factors controlling fire hazards will be possible.

It is true that the water service is only one element in a very complex problem; that the character of building construction and the efficiency of the fire department are of almost or quite equal importance, and that the basic rate applicable to any city must be a product of several factors, each subject to modification as made necessary by the local conditions. With due appreciation, however, of the complexity of the problem, it is believed that a more logical co-relation of the character of the water service and the fire hazard can be developed. The possibility lies in the extension of schedule rating by which rates will be scientifically developed from the accumulated experience of underwriting associations in such a way as to gradually eliminate the personal equation and the discrepancy now existing in the assessment of individual risks. In such rating the proportionate effect of the water service would be determined and the relative value of works of different character made known to municipal authorities.

The ultimate end of insurance associations is not merely the payment of losses; another and most important factor is the work which has been done toward the reduction of the fire hazard by investigations, inspections, and insistence on certain standards of construction and fire fighting facilities. From the standpoint of the insurance company, prevention of conflagrations is a better means of profit than high rates, a result proved by the success of the factory mutuals in which the primary motive is the prevention of fires by the provision of specified standards of construction and facilities for preventing conflagrations. In these companies, rates are scheduled, disabilities penalized, and improvements rewarded with definite financial returns. And it is probable that, as schedule rating, scientifically deduced from the accumulated experiences of many companies and developed by some central controlling board of underwriters, becomes the rule, methods approximating those of the above-mentioned companies will be made applicable to general insurance, in which case deficiencies existing in the different municipal departments which have a controlling influence on the conflagration hazards will be definitely expressed as penalties in increased rates which, by certain improvements, can be removed.

As an illustration of schedule rating brief reference may be made to the Universal Mercantile Schedule developed in 1893 which, in some parts of the country, constitutes the principal basis of rating at the present time. By this schedule a key-rate was to be given each city and town, differing in each as was made necessary by local conditions. These key-rates were to be modified for individual risks in accordance with the variations in construction, occupancy, and other particular hazards; and as a basis for the establishment of the key-rates a standard building in a standard city, with gravity water works, adequate distribution system, efficient fire department, and other attributes, was conceived, and for such a building in such an environment a basic rate was adopted from which the key-rates of other cities might be obtained by additions made for certain deficiencies. This schedule was by no means perfect, and has been criticised in several particulars, but for the present purpose it serves to indicate the possibility of schedule rating and the advantage of definitely making known to each community its standing in the rating problem, its deficiencies and the penalties exacted, and finally the improvements necessary to obtain the basic rate of the ideal city. Under such a method, definite incentives to improved standards in the water service, fire department and building construction are presented by the resulting reduction in rates often made possible of attainment without increased cost to the community. And beyond all this, in broader outlook, there is the possibility that by such co-operation of municipal authorities and underwriting associations a long step would be taken toward the actual conservation of property values by lessening the fire losses, which the payments of insurance never can make good, and which, at the present time, in this country, equal ten times the losses in Europe in amount per capita.

DISCUSSION.

THE PRESIDENT. Mr. Barbour's paper is now before you for discussion.

MR. CHARLES E. CHANDLER.* I have been very much interested in Mr. Barbour's paper, and as discussion is perhaps best

* Civil Engineer, Norwich, Conn.

induced by some people taking the opposite side, I would say that, having occasion as chairman of a committee of the Connecticut State Board of Trade to meet insurance men comparatively recently, since the San Francisco fire, I take considerable interest in fire insurance. You remember that fire insurance rates, especially on mercantile property, were very largely increased a year or two before the San Francisco fire, and when that fire occurred the merchants and others had just got reconciled to those increased rates. Then the San Francisco fire stampeded the insurance companies, and they immediately made a large raise, 20 cents a hundred, in mercantile rates in what they called conflagration areas. That naturally raised a storm of protest, and committees were appointed from all sorts of trade organizations to treat with the insurance people. The result of it, or at least these committees claimed the result of it, was, that the companies dropped the 20 cents within a short time. They dropped it anyway, whatever the reason was, and perhaps they felt that they had made a mistake in having put it on at all.

But it seemed to be developed by conferences with the representatives of insurance companies that they had an idea that the fear of punishment was a better incentive to improvement in fire service than the hope of reward; at least it seemed as though that was the incentive they used generally. It also appeared that the idea of establishing rates on the principle of putting on all the traffic would bear was very generally followed. They admitted to us that Connecticut was one of the best states in New England in their past experience, that they derived more profit relatively from Connecticut than any other New England state, and when asked if we in Connecticut got better rates than they did in some other places, like Maine, for instance, they said, "We couldn't do business in Maine if we charged them as much as we charge you." [Laughter.]

Mr. Allen Hazen.* It seems to me that this question of fire protection and insurance rates is one that will solve itself in our cities during the next generation. The solution will come by the adoption of better methods of building. Concrete masonry floors will take the place of the wooden floors that are so com-

* Of Hazen & Whipple, Consulting Engineers, New York City.

monly used at the present time, and the change already beginning is bound to go on at an accelerated rate. This change and other improvements in building methods will bring us to the condition which has already been reached in some European cities, where the fire risk is so slight that it is not worth while to insure buildings and it is not worth while to lay the pipes of the water-works system larger than would otherwise be needed, in order to provide fire protection. In other words, the pipes are provided simply for the distribution of the water for domestic purposes and not for its concentration in large quantities on fires. This condition is bound to prevail ultimately with us, and it may come sooner than we now think. In the meantime, we have thousands of wooden buildings and buildings with wooden floors in all of our cities, and we must take care of them, for we cannot afford to lose them now, and while they last provision must be made for concentrating large quantities of water upon the fires that will inevitably take place in them, in order to prevent the spread of those fires with the destructive results which have been experienced too frequently by our cities.

The cost of providing the pipes and facilities for supplying this water from time to time in large quantities is very great. Some one must pay for it, and I believe that the more the expense of doing it can be put upon that class of buildings for which it is alone necessary, and the more that can be done to relieve from the tax the buildings that are fireproof, or substantially so, and do not profit by the service, the better it will be for the water departments and for our cities.

President Martin. I think when that time comes, Mr. Hazen, the school department of the city of Springfield, Mass., will throw up both its hands and require us to furnish all the water we can furnish for running motors. They advance the argument now that we have plenty of water standing idle in the pipes, and say, "Nobody wants it, why can't we use it?"

Mr. Leonard Metcalf.* It seems to me that the remarks of Mr. Chandler but give point to some of the suggestions which Mr. Barbour has made as to the responsibility of water works officials to see to it that the ball is started rolling in the effort to get re-

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

duced insurance rates after radical improvement of the fire protection service. One of the difficulties, of course, in obtaining recognition from the city — the different departments of the city — for the benefit of the water department comes about from the intrusion of politics into the management of city affairs, and also from the desire of the different departments to make as good a showing as they can, so the water department has to bear the burden of making the improvements without getting corresponding recognition. The reduction in the insurance rates unfortunately does not go back to the city treasury nor to the water department, but to the individual, and so perhaps naturally it comes about that the water department postpones making improvements, which it recognizes should be made under existing conditions, in any particular city, until such times as the rates will enable them to do it, although they recognize perfectly well that the improvement should be made and that the saving in insurance rates would largely exceed the interest and other charges of the improvement.

Along this line I have been much interested in two or three cases which have come to my personal notice, following upon the taking of the water companies' property in certain places in Maine, in which water districts had been formed and the properties of the local companies taken over. In several of those cases, at least, the works have been virtually rebuilt, larger mains have been put in, and the fire service has been very materially improved. In some cases there has followed a reduction in the insurance rates. In those cases, under the Maine law, the department is operated as any corporation would be, independent of the city, the revenues being derived from the rates. But the city itself has not availed itself of the opportunity to get improved fire service by the placing of additional hydrants upon the system. In one case, for instance, at Waterville, Me., I remember we recommended that, owing to the distance apart of the hydrants, something like fifty hydrants be placed upon the existing and the new mains, at a nominal cost to the city. The result was, as I remember it, that they placed at first six hydrants and subsequently three more. As a matter of fact, the entire expense of the improvement was caused by the recognition of the fire district

trustees of their responsibility in the matter — their responsibility to furnish the city with a proper fire service — and yet the city officials, or the city council, was not willing to recognize the work to the extent of availing itself of the improved service. This difficulty has been obviated in some measure by offering, for a certain small nominal increase in rental, to place any number of additional hydrants which the city might desire upon existing mains, at the bare cost of placing them there. That perhaps is one step in advance of the old condition, but it is not a fair recognition of the work which the water department has done. I should suppose that competitive conditions in insurance would tend to bring about a reduction in insurance rates after an improvement of the service, but Mr. Chandler's remarks give point to the fact that even that influence does not always work.

THE ADJUSTMENT OF DIVERSION DAMAGES BY STORAGE COMPENSATION.

BY ROBERT E. HORTON, HYDRAULIC ENGINEER, ALBANY, N. Y.

[*Read September 24, 1908.*]

DEFINITION.

Storage compensation, or "compensation in kind," may be defined as regulation of the flow of a stream in such a manner as to compensate for water diverted, by drafts from storage during dry times, in such a manner that the flow of the stream shall never fall below a certain minimum fixed by agreement or adjudication. Such compensation would be furnished in lieu of, or in addition to, money damages for the diversion of water.

ENGLISH PRACTICE.

Compensation in kind apparently originated in England, although I have been unable to find the place or date of its origin. Clemens Herschel, who has given much study to the matter, says that for a hundred years or more this has been and yet is the accepted method in Great Britain. In England the use of compensation in kind in lieu of money damages may be determined upon by an act of Parliament in any case. The act, or a Parliamentary commission sitting as a court, fixes the rate of compensation as some fraction of the available flow. It is customary to deduct one sixth from the total yield of the stream to allow for freshet flow, which it is impracticable to store or utilize. The remaining five sixths is considered as the available flow, and the conditions of compensation require that the stream shall be so regulated that the flow shall at no time be less than a given fraction of the available flow. Humber says: "Mills are never designed to utilize the whole of the water flowing down a stream; by far the larger portion runs to waste, partly in times of excessive rain, and partly when the mills are not at work. The proportion of water utilized necessarily varies in different cases, and it is upon

this point that most of the contention between the promoters of water works and the owners of mills arises. It is ordinarily found that mills are capable of using only from one fourth to one third [of the available flow], and one or other of these proportions, mostly the latter, is generally assigned as the quantity to be passed uniformly and constantly down the stream as compensation." In a characteristic manner the English have reduced this matter to simple but rather arbitrary rule. English practice in compensation varies somewhat from the one-third rule, however, as illustrated by the following examples, collected from Tudsbury and Brightmore's "Water Supply Engineering":

City.	Stream.	Rate.	Date.	Remarks.
Liverpool	Vyrnwy	One-quarter	....	Industries unimportant
"	Rivington	One-half	1847	
"	"	About one-third	1868	Reduced by purchase
Manchester...	Longendale	Two-fifths	1848	Important industries
" ...	"	One-third	1854	Reduced by purchase
" ...	Thirlmere	About one-tenth	1879	

It will be noted that in two cases the original compensation rate has been subsequently reduced by purchase because the drainage basin was incapable of supplying both demands in full; thus the prime object of compensation in kind has been in some degree nullified.

Obviously there can be no uniform basis for compensation in kind that is applicable to all streams and which is just. The basis and method of compensation should differ according to the variability of the stream, the cost of storage development, the amount of storage which it is feasible to develop, the extent and character of the power development, and the amount of diversion to be made. The general principle may be laid down that for each business and water-power site there is some particular size of development that will yield a larger return per dollar invested than any other size. Any development that does not exceed this limit is a reasonable development, and the basis of compensation should be such as to do it no injury, even though it may require a higher basis of compensation than any other power on the stream.

DIFFICULTY IN EMPLOYING "COMPENSATION IN KIND" IN THE UNITED STATES.

The reason why compensation in kind cannot be made a legal remedy in the United States is that, under the Constitution, property cannot be taken without just compensation, and the United States Supreme Court has ruled that just compensation can only be measured and properly rendered in money.

I do not want to be understood as favoring the compulsory acceptance of compensation in kind as a legal remedy for diversion. There is little doubt that its adoption in this country on the same basis as in England would work a grievous injury to one of our greatest natural resources, —water power.

I believe that compensation in kind by mutual agreement is in some cases the best and cheapest method of adjusting diversion damages. If a prospective water supply would only injure a single riparian owner, it would more often be possible to adjust diversion damages by storage. It is usually the case, however, that a number of mill owners with a wide diversity of interests are to be dealt with, and the real difficulty is to secure concerted action among them. The same difficulty arises in the development of storage, in attempts to substitute central power stations for the wasteful system of distribution of power by hydraulic canals in the old mill towns, and in the development of irrigation and drainage projects. In the case of the two last named, legislation has been adopted in many states by which the will of the majority rules the community as a unit in the execution of such works. If legislation is adopted whereby all may be compelled to join in projects for the regulation of streams by which all will be benefited, a légal difficulty in the way of equitable adjustment of damages by stream diversion will be removed.

Frizell, in his "Treatise on Water Power" (pp. 539–540), suggests a form of law such that no one should be compelled to join in a storage project, but any one failing to pay for such storage should be required to pass down stream unused a quantity of water equal in amount to that fed into the stream from storage.

Such a law would aid to secure the coöperation of such persons as will, under present conditions, hold off in hope of securing the

benefit without payment; and who also, in case of diversion, might secure money damages and at the same time benefit by the compensation reservoirs built to indemnify their less swinish neighbors.

THE NEWTON, N. J., CASE.

In this case, as described by Mr. Louis L. Tribus, a lake was raised 5 feet and the mills were given full control of the resulting storage. They did not release the parties making the diversion, however, and although benefiting by storage and suffering no actual reduction in their power, they brought suit to recover for the diversion made. The court awarded damages of $3 302 for 2.65 continuous horse-power in one case, and $2 650 for 2.54 continuous horse-power in another case. These awards were made on the basis of capitalized cost of substituting steam-power. The higher court reduced the awards to $500 for 2.54 horse-power and $750 for 2.65 horse-power, the new awards being based on the difference in the value of the property before and after the diversion.

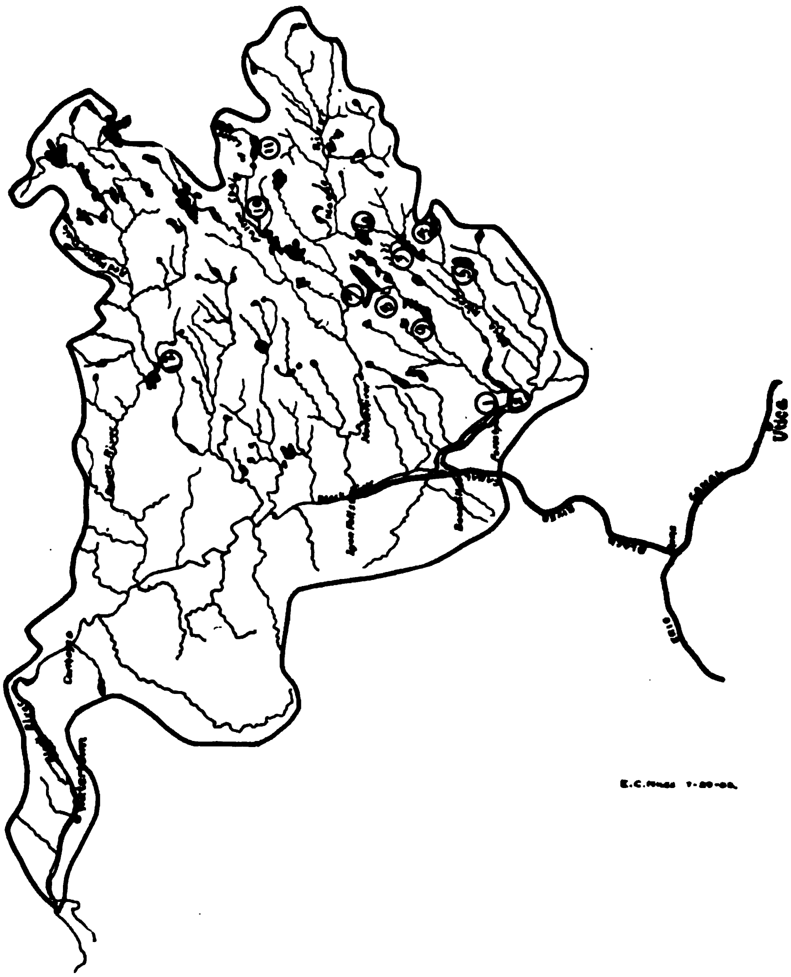
Clemens Herschel states that compensation reservoirs were actually built about sixty years ago in connection with the first Cochituate water works of Boston, but could not be used under American laws. I presume that there are other instances where compensation in kind has been used or attempted in this country to which my attention has not been called, and I believe those having the data of such cases should place them on record before this Association.

AN EAST CANADA CREEK CASE.

Power is developed at Beardsley Falls, on East Canada Creek, N. Y., under a head of about 120 feet. The city of Little Falls derives its water supply in part from Spruce Creek, a tributary entering East Canada Creek several miles above the power plant. After considerable litigation the matter of diversion damages was settled out of court, the writer being consultant to the power interest.

The city is allowed to take water from Spruce Creek without restriction upon condition that it shall perpetually pass down stream from its storage reservoir at Salisbury a depth of 3½ inches

at least, on a weir 18 feet long. This corresponds to 9.36 c. f. s. The intention was to provide an ultimate water supply of 6 000 000 gallons per twenty-four hours for the city, which also amounts to



MAP SHOWING COMPENSATION RESERVOIRS ON BLACK RIVER.

about 9.36 c. f. s. The tributary drainage basin of Spruce Creek is 36.2 square miles.

COMPENSATION IN KIND ON BLACK RIVER, N. Y.

The summit level of Erie Canal at Rome is about 25 miles south of the point where the Black River emerges from the southwest slope of the Adirondacks. Black River Canal extends northerly from Rome, connecting the Erie Canal with the navigable portion of Black River below Lyons Falls. Black River Canal also serves as an important feeder of the Erie summit level, supplying it with water diverted from Black River at Boonville. The geographical relations are shown on the accompanying sketch map (page 338).

There are numerous water powers along Black River from Carthage to its mouth, many of which were in use before the original diversion was made in 1849. The Boonville feeder was constructed to carry 267 c. f. s., but the natural minimum flow of the river at Forestport, which is the point of diversion, is only about 117 c. f. s., and during dry times, before the reservoirs subsequently described were constructed, practically the entire flow was diverted. Part of the diversion passes northward, supplying Black River Canal from Boonville to Lyons Falls, where it again enters Black River, and the remainder is permanently diverted, passing southward through Black River Canal and entering the Erie Canal at Rome. As soon as the Boonville feeder was put in use, complaints arose from mill owners, and claims for damages were filed. Part of Black River was, however, a navigable stream and a part of the state canal system, and the question arose and has never been decided, whether the state might not have taken such waters as it needed for navigation purposes without being held liable for damages. Precedent indicated that remuneration might only be obtained through the legislature. It was clearly the policy of the state to protect the industries along its canals, and accordingly Chapter 181 of the Laws of 1851 was enacted, providing for examinations of reservoir sites on Black, Beaver, and Moose rivers, directing the construction of, and appropriating money for, " reservoirs of sufficient capacity to supply the Black River Canal feeder with such quantity of water during the summer months as shall be necessary for the supply of Black River and Erie canals, and as shall give to the Black River, as near as may be, as much water as ordinarily flows therein during the summer months."

Apparently this basis of adjustment was quite satisfactory to a

majority of the riparian owners, although the delays incident to carrying out the provisions of the law caused further trouble. While I have seen no record to that effect, I have reason to believe that this act was drawn at the instance of the riparian owners, and to meet their wishes, and that this mode of compensation was not forced upon them.

The first reservoir was not completed until ten years after the feeder was put in use. Other reservoirs have been completed from time to time, the system at present being as shown in the subjoined table.

STORAGE AND COMPENSATION RESERVOIRS ON BLACK, BEAVER, AND MOOSE RIVERS.

Number on Map.	Name.	Tributary Area, Square Miles.	Approximate Storage Capacity, Cu. Ft.
	BLACK RIVER.		
1	Forestport Pond	86.46 (*a*)	13 068 000
2	" Reservoir	106.48 (*b*)	213 444 000
3	North Lake	27.76	301 653 000
4	South Lake	5.97	421 312 000
5	Twin Lake	4.77	68 607 000
6	Canachagala Lake	2.08	139 392 000
	WOODHULL CREEK.		
7	Woodhull Lake	9.40	876 601 000
8	Sand Lake	3.00	239 928 000
9	Chub Lake	9.87	34 848 000
	MOOSE RIVER.		
	Fulton Chain of Lakes.		
10	1st to 5th	35.23	352 000 000
11	6th to 7th	17.78	300 000 000
	BEAVER RIVER.		
12	Beaver	153.00	900 000 000
	Total	461.80	3 860 853 000

(*a*) Woodhull Creek, not including Black River.
(*b*) Not including Woodhull Creek.

The present average diversion, taken from the mean of many measurements, is as follows:

Flow in feeder, near mouth	298 c. f. s.
Northward flow, returned to river	79 "
Southward flow, diverted	205 "

This apparently is a notable instance of compensation in kind on an unusually large scale, and comprising some peculiar features.

Two sets of reservoirs are provided, one to increase the supply that may be diverted, to an amount greater than the minimum flow; the other set for compensation. Originally the control of all the reservoirs was vested in the Canal Commissioners, but in 1896 a law was passed giving a commission of three water-power users complete control of all compensation reservoirs.

The law of 1851 failed to specify how many reservoirs should be constructed. The natural result has been a continued struggle on the part of the mill owners to have the reservoir system extended. It appears, however, that not until recently has the reservoir system been adequate to comply with the requirements of the law. No reliable gagings were made in the early years to determine the low-water flow, and the water-power users have been disposed to magnify its amount. It has been commonly reported among the riparian owners that the minimum flow in the vicinity of Watertown is 2 000 c. f. s. I have conducted careful gagings of the stream for several years which show several low-water periods with a flow of only 800 to 1 000 c. f. s., with the reservoirs in operation.

A practical difficulty with so large a system lies in the necessity of placing some of the reservoirs at a distance from the point of diversion. In this case some of the reservoirs are on the Moose and Beaver rivers, tributaries that enter Black River at a distance below Forestport, and there is left an intermediate reach of the river on which there are some water powers that suffer the full effect of diversion and receive little compensation water.

A NEW TYPE OF COMPENSATION IN KIND.

Diversion from West Canada Creek for the water supply of the city of Utica is compensated under contracts with the Utica Gas and Electric Company, owners of the Trenton Falls power plant, and the International Paper Company, which controls the so-called Herkimer hydraulic canal. These are the largest water-power users on the stream, the development being as follows:

	Drainage Area, Sq. Mi.	Head, Feet.	Approximate Turbine Cap.
Trenton Falls................	375	265	333
Herkimer....................	583	30 to 33*	385

*At upper or paper mill level; 12 to 15 feet additional fall on lower level.

The principal provision of the contracts is to the effect that the Water Company may divert, without compensation, from any excess flow over the amount required by the plants in question. The Water Company may either divert such water directly or impound it in storage reservoirs for use in times when the natural flow does not exceed the requirements of the mills. This apparently simple arrangement is, so far as the writer is aware, the first of its kind. It has been in use two years and is found to be practicable to carry out in operation.

The conditions to be met were as follows: The Gas and Electric Company contemplated a progressive scheme of power development in which the construction of storage reservoirs as a private enterprise forms an element. The Water Company, on the other hand, desired that the amount of its diversion should be without restriction. It is believed that both of these requirements are satisfied. In the first place the Water Company cannot take any water which would otherwise be actually used by the power interests; hence, if the capacities of the power plants are increased, the limit above which the Water Company can divert without compensation will simply be raised. In the meantime, the Water Company is enabled to divert above a lower limit, and in so doing it works no injury to the existing power development, but is itself saved the outlay for enlarged compensation reservoirs until actually required. It might at first appear that the power interests, by sufficiently extensive installation and storage, could practically prevent the Water Company from taking any water. As a matter of fact, the Water Company is definitely assured of an abundant supply for any reasonable future demand. This assurance rests upon the facts, first, that it is impracticable to completely regulate this stream by storage, and second, the Water Company controls storage sites sufficient for its own requirements with any reasonable basis of power development.

West Canada Creek is an excellent water yielder, situated on the southwest slope of the Adirondacks, where the moisture-laden winds from Lake Ontario precipitate the maximum amount of rain and snow. Gaging records for dry years indicate that with the present basis of power development it will never be necessary to compensate during more than one hundred to one hundred and

twenty days without opportunity to replenish the storage, and even so long a period of deficiency will probably occur on an average only a few times in a century.

It follows that by providing a storage capacity equivalent to say one hundred days' supply the Water Company is enabled to make perpetual diversion. The present diversion is 6 000 000 gallons per day, and will be increased to 10 000 000 gallons per day in the near future. Of course, no effort is made to secure identity of the diverted and compensatory waters. The compensation reservoirs may be located at any point in the drainage basin, but if remote from the water supply intake, a reasonable time allowance is to be made between letting down the compensation and making the diversion. The real purport of these contracts is that whenever the flow in the stream at either of the mills is less than the amount required for power, the Water Company, if it is diverting water at its intake, likewise turns into the stream an equal amount of stored water, so that there is no change or diminution at any time in the flow utilized by the mills. The contracts are thus entirely flexible as to the amount of power that may be developed, or the amount of diversion that may be made so long as the capacity of the stream is not exceeded. The Water Company is under bond for the fulfillment of its contract, and in case of its failure, the power interests have the same remedies at law as if no compensation had been attempted.

One feature of the system is the maintenance of accurate weirs and gages to determine both the inflow to and the outflow from the storage reservoirs, as well as the flow in the West Canada Creek above the Gas and Electric Company's plant, and again near the mouth of the stream, above the Herkimer mills.

Carrying out the provisions of these contracts costs the Water Company a moderate amount, but, on the other hand, the pecuniary value of the compensation may be judged from the fact that the diversion of 10 000 000 gallons per day under 265 feet head, as utilized at Trenton Falls, would represent the destruction of 325 net horse-power.

The contracts were drawn jointly by several attorneys of experience in matters of water rights, with the assistance of the writer.

CONCLUSIONS.

1. Compensation in kind should not be attempted on a stream where the natural low-water flow plus the feasible storage development will not supply more than the total requirement for water supply and power.

2. Arbitrary rates of compensation should be avoided. The basis of compensation should be made so flexible as to admit of the best utilization of all the water of the stream in the most economical manner.

3. Legislation should be secured by which the will of the majority of riparian owners can be enforced in the matter of storage development and stream regulation, and which will prevent a minority of the riparian owners from either blocking a storage or compensation project, or from receiving benefits therefrom for which they do not pay.

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DISCUSSION.

MR. CHARLES W. SHERMAN * (*by letter*). Reference has so often been made to the attempts to furnish "compensation in kind" in connection with Boston's Cochituate Water Works, that an authoritative statement of just what steps were taken and of the results

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obtained may be of interest, especially as the information is not readily available to many. The following data from Bradlee's history of the Boston Water Works * are accordingly submitted:

"The purchase of White Hall Pond, in Hopkinton, was made November 4 [1846], by the Committee on Water, under the resolve passed April 21, . . . for the sum of $25 000, with the intention of using it as a Compensating Reservoir to flow into the Concord River as a substitute for Long Pond water, whenever that should be diverted from its natural channel to the injury of those who were entitled to the use of it." . . . "The actual cost of this Reservoir, after the dam was built and the improvements made, was $29,534.36." (Page 100.)

"At this time [December 13, 1847], the [Water] Commissioners thought it best to build Compensating Reservoirs, to serve as a substitute for the waters which might be diverted from Concord River, and at their request the following order was passed [by the City Council]:

"*Ordered;* that the Water Commissioners be authorized to make such purchases of lands and water rights in the name and on account of the city of Boston, and to erect such dams, embankments, and other works, as they shall deem necessary and expedient for forming Reservoirs of water to serve as a substitute for the waters which may be diverted from Concord River, and to make payment therefor, in the same manner as for lands and water rights purchased by virtue of the act for supplying the city of Boston with pure water; *provided,* the same does not exceed the sum of fifty thousand dollars." (Page 71.)

"January 13, 1848, the Commissioners purchased of Mr. Amory Maynard, the Marlborough and Boon Pond Reservoir, for the sum of $21 148.90; they finally cost, however, when the dam was completed and the reservoir ready for use, $43 170.59." (Page 109.)

In 1854, the Whipple suit for damages for diverting the waters of Lake Cochituate from Concord River was brought, and resulted in the settlement of all claims for $6 678.90. (Page 170.) This seems to have demonstrated the futility of the attempt to furnish "compensation in kind."

"The Marlborough Reservoir was sold this year, July 29 [1858], to Mr. Amory Maynard, for the sum of $8 000." (Page 184.)

* N. J. Bradlee: "History of the Introduction of Pure Water into the City of Boston, with a Description of Its Cochituate Water Works." Boston, 1868.

In 1859, "the proprietors of Sudbury meadows . . . memorialized the city of Boston for payment for damage done their property by letting down water from the reservoir at unseasonable times." . . . The water board finally proposed that —

"The city of Boston will convey to some responsible agent or committee, authorized to act in behalf of the proprietors, by quitclaim deed, all the right, title and interest which the city possesses in and to the reservoir [Whitehall Pond], at Hopkinton, with its dam, gate-house, and flume, to have and to hold, and lawfully manage and control the same as they please." (Page 193.) This was done.

Mr. Louis L. Tribus.* If I had known, Mr. President, that the Newton case was to be brought up here, I would have been very glad to have shown a map exhibiting some features, which were rather interesting in some respects. It is one of the few cases in this country where a reservoir has been actually constructed partially — not wholly, as the paper under discussion would seem to indicate — for the purpose of compensating in kind. The town of Newton, N. J., was not a riparian owner on the stream in question, so could only act through "agreements" rather than by "rights." On this stream there were three mills, neither one having storage capacity to supply other than a daily regulation of the mill use. The upper owner, about forty years or so before the Newton work was carried on, diverted a small stream from its natural course into an artificial pond made at the outlet of a natural lake, the combined flows later reaching the same original brook. Many years ago the level of the lake was raised slightly by a small earth dam, but this, following construction of the lower pond, was allowed to practically disappear so that the waters of the pond and lake were reasonably free to flow back and forth. This upper owner used at will the natural flow of the stream and the outflow from lake and pond, without regard to the interests of the lower owners who had no interest, through ownership, of any pondage along the upper stream.

Newton bought some of the rights of this upper owner and the fee in the original lake. It fully diverted the upper stream, the one that this original owner had partially diverted into the upper lake, and erected a substantial masonry dam, raising the high

* Consulting Engineer, New York City.

water level some five feet. In that upper five feet there was stored at least twice as much water as would suffice the uses of the town of Newton for a whole year, and that upper five feet could easily be stored in two days' flow of an ordinary winter or spring storm from the direct and diverted watershed. In fact, it has been filled in about twenty-four hours.

The speaker, as engineer for the town, urged the commissioners to enter into written agreements with the lower mill owners. They thought, however, that in view of the expenditure that Newton was incurring for raising the level of the upper lake and the general friendly feeling for the enterprise, there would be no need of an agreement, as there were no actual physical damages, but, instead, betterments. The agreement with the upper owner was such that he was to control the gate of the lower pond at will, and the town was to feed the lower pond from its stored waters as he should require, keeping the water level in the lower pond practically at a standard.

The lower owners made no objection, the works were built, and things went on for nearly two years, the mills all receiving a distinct benefit; but then suits were brought, and the court decided, on the old principle of law, that damages must be recognized in money and that theoretically (it could not say practically, because there was no practical damage) these owners were deprived of the amount of water that Newton could take through its mains out of the watershed into another watershed; therefore, it was the flow of a 10-inch pipe (the main line) for twenty-four hours for 365 days in the year which must be made the basis of an award for damages. The upper owner from whom much of the property had been purchased had grace enough not to bring any suit at that time. He, however, did bring a suit later which, after a lengthy trial, was settled out of court for a small sum. He ought never to have won in view of the special considerations in his case, but the court would probably have awarded damages on the technical questions involved rather than actual damages incurred.

MR. ALLEN HAZEN.* I am under the quite distinct impression that the city of Fitchburg, Mass., has compensated mill owners

* Of Hazen & Whipple, Consulting Engineers, New York City.

in kind, and built a reservoir and turned it over to the mill owners, to be operated in lieu of water diverted from other tributaries of the stream for uses of the city; but it is my impression that that arrangement was carried out by agreement and could not have been carried out in any other way. I do not want that to be taken on my statement, but some one should make a definite statement of it and it should go in the record, I think, in connection with these other cases.

MR. THOMAS H. MCKENZIE.* I happen to be familiar with one instance in which compensation in kind has been made, at Meriden, Conn.; that was partly by agreement and partly by legislation. All of the mill owners agreed to a certain size and capacity of reservoir in lieu of money damages, and the city of Meriden secured legislation authorizing the construction of the compensating reservoir and the issuing of bonds to cover the cost, and I believe the arrangement has worked very satisfactorily. That is the only case which has ever come to my knowledge.

MR. HAZEN. I think, Mr. President, if the principle could be established there would be many cases where developments would be possible that are not considered possible under present laws, and that great good might come from it both to some of our cities and also to manufacturing corporations upon rivers.

MR. LEONARD METCALF.† Mr. President, just to get the matter on the record, it may be well to mention that I think something of the sort was done by the mill owners on the Blackstone River, — I should have said the Draper Company took the initiative in the matter, — and they built a dam at North Pond for storage purposes solely. I think that Arthur T. Safford, of Lowell, will probably know the facts in regard to the matter, so it can be looked up in connection with this paper.

MR. DAVID A. HARTWELL ‡ (*by letter*). In 1891 the city of Fitchburg was greatly in need of an additional water supply, and two natural ponds in the town of Westminster seemed the most desirable of any possible source. These were Meetinghouse Ponds with a water surface of 152 acres and a watershed of 942 acre (including the pond), and Wachusett Lake, partly in Westminster

* Consulting Engineer, Southington, Conn.
† Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.
‡ City Engineer, Fitchburg, Mass.

and partly in Princeton, with a water surface of 134 acres and a watershed of 976 acres (including the lake). Franklin Wyman owned and operated a paper mill at what was called "The Narrows," and controlled the waters of Meetinghouse Pond and Wachusett Lake. He also had a storage reservoir called Wyman reservoir above his mill, with a watershed of 3 032 acres in addition to the water sheds of Meetinghouse Pond and Wachusett Lake, the overflow from which enters said Wyman reservoir. The dam of the Wyman reservoir was in such poor condition in 1891 and for some years previous thereto that the county commissioners would not allow him to fill it.

The city of Fitchburg purchased of Mr. Wyman, for $75 000, all his storage and flowage rights, his paper mill and adjacent houses and other buildings and a considerable area of land. Section 4, Chapter 60, of the Acts of 1892 of the Massachusetts Legislature relative to an additional water supply for the city of Fitchburg reads as follows:

"Said city is also authorized to take and hold, by purchase or otherwise, the water of Wyman reservoir, so-called, in the town of Westminster, and the waters which flow into and from the same, and any water rights connected therewith, to be used as a compensating reservoir for all damages that would otherwise arise to mill owners by reason of the taking and diverting of the waters of Meetinghouse Pond and Wachusett Lake; and to take and hold in like manner such lands as may be necessary for building, erecting, and maintaining a dam for storing and distributing said waters. Said city is authorized to contract with mill owners whose rights are affected, in relation to the manner and mode of using, controlling, and operating said compensating reservoir."

Acting under this section the city built a new dam for the Wyman reservoir so as to store up to the limit of the flowage rights, which raised the level of Wachusett Lake about four feet. The cost of this dam, including the gate house and contingent work, was about $50 000. This compensating reservoir, not including Wachusett Lake, has an area of 203 acres and an available storage of 419 000 000 gallons.

An agreement was made with all the mill owners on the north branch of the Nashua River and the mill owners on the main river between the junction of the north and south branches at Lancaster

and its confluence with the Merrimac at Nashua. By this agreement the mill owners released all rights to the waters of Meetinghouse Pond and Wachusett Lake and the city built the Wyman dam. That part of the agreement relating to said Wyman reservoir reads as follows:

"Now, therefore, the said city hereby covenants and agrees with the said parties of the second part, and with each of them, their heirs, executors, administrators, successors, and assigns, that it will forever maintain said reservoir at its present capacity for the sole use and benefit of said parties of the second part, their heirs, executors, administrators, successors, and assigns, and that it will take whatever measures are necessary to prevent any interference with, or diversion of, the waters which flow into the same and the sources of supply by which the same is filled, and that it will forever keep the walls and gates of said reservoir in good repair so that the water thereof, and no part thereof, shall be allowed to escape except as hereinafter provided, and that it will forever keep and maintain in good repair the dam now located at the eastern end of said reservoir at its present height and that it will construct and forever maintain at the eastern end of said reservoir a proper gate or gates to control the waters of the same, and that it will always supply and employ a suitable man, or men, at its own expense, to care for said gate, or gates, at said dam, and to so adjust the same that there shall be as nearly as possible an uniform flow of water, each and every day, except Sundays and legal holidays, throughout each and every year hereafter, into the natural channel as it exists to-day, and to so adjust the said gate or gates that said flow of water shall be as great as possible consistently with the uniform flow thereof; that it will permit none of the waters of said reservoir to be used for any other purpose than is herein provided, and that the said waters of said reservoir shall at all times when said gates are open flow unused and without interruption of any kind into the said channel, and shall be used for no other purposes except as a part of the waters of the Nashua River after they shall have gone into the said stream, except, however, and it is hereby expressly provided, that it shall be lawful for the city in case a serious conflagration occurs in West Fitchburg, or in the city of Fitchburg proper, or in case the pipes which carry the waters of Wachusett Lake and Meetinghouse Pond into the city of Fitchburg shall break above the said Wyman's reservoir, to draw the waters of the said reservoir into the pipes which form the city's system of water supply, during the existence of said conflagration, or until the said break shall have been repaired by due diligence on the part of the city."

Thus the city of Fitchburg, with an expense of about $125,000, purchased water rights and settled all claims for loss of power by which, under proper development, was made available an additional supply of about 4 000 000 gallons a day.

MR. T. H. MCKENZIE (*by letter*). I happen to know of one instance in which compensation in kind was made by the city of Meriden, Conn., to the mill owners on Sebethe River in the town of Berlin, in the year 1868.

The city of Meriden diverted the water from one square mile of watershed which was tributary to six mills which were in operation and one mill privilege not in operation. The fall at the privileges in operation was about as follows: 18, 14, 36, 12, 8, and 8 feet; total, 96 feet fall. The compensating reservoir cost $18,000, which is equivalent to $187.50 for each foot fall for one square mile of watershed.

This settlement was by agreement with the mill owners to accept a certain size and capacity of reservoir in lieu of money damages, and afterwards by the city of Meriden securing legislation authorizing the taking of land and the issuing of bonds to cover the cost of construction. The reservoir is of 52 000 000 gallons capacity. The arrangement worked satisfactorily for many years.

At the time the reservoir was built, three of the falls, 18, 36, and 12 feet, respectively, were owned by one company; this same company owned property below the compensating reservoir, and above all of the mills another storage reservoir of double the capacity of the compensating reservoir. The water from the compensating reservoir had to pass through this large reservoir before reaching the factories. The company owning the three falls of 18, 36, and 12 feet, by common consent of all of the mill owners, controlled the gates at the compensating reservoir as well as the other large storage reservoir. In course of time the large company sold the mill with the 12-foot fall, but did not sell their rights in the large storage reservoir. Then trouble began to brew. The owner of the large powers who controlled the gates drew all of the water from the compensating reservoir and still held the water in their storage reservoir. The large company found it necessary to shut down their factories for a month in July, when the party below with 12-foot fall wanted to run; very little water was running in the

stream, not enough to run a mill, so a suit was brought against the large company to compel it to let water down. The large company claimed that the water was all drawn from the compensating reservoir and that the water in the large storage reservoir below all belonged to them as it was stored water from the spring floods. The large company won in the suit, and held the water.

Aside from this one incident, the plan of compensating in kind might be called a success in this case, although if one of the proprietors of the mills wished to put his property to other use than for power purposes, the stored water would be of little use to him, while the money would be useful and would be drawing interest.

As to the saving in the Meriden case, it is somewhat doubtful about any saving in cost. The cost of the reservoir in the Meriden case was about $187 per foot fall for one square mile.

The cost in a large number of cases in which I have been engaged and where money damages were paid ranged from $100 to $210 per foot fall per square mile of watershed diverted. This price refers to mill powers which are actually developed and in operation. In the Meriden case, the cost of the compensating reservoir figures about $200 per foot fall per square mile of watershed diverted.

Where a large number of mills are to be settled with on a stream it would be much cheaper to settle by storage of water.

Where only a few mills are to be settled with and a small area of watershed is diverted, it would be cheaper to settle by paying money for damages.

I doubt, however, about any general law being enacted that will compel the claimants to accept something in lieu of money for damages.

The matter of drawing off the water and controlling the gates of a storage reservoir which is owned in partnership is a difficult problem to handle. One party may want to run his mill and another want to shut down his mill and save the water.

I had occasion a few years since to make surveys and plans for a large storage reservoir on the east branch of the Farmington River in the town of Otis, Mass., for the Farmington River Power Company. There were originally seven equal owners in the company, which was organized for the purpose of building the first storage reservoir on this stream. After the reservoir was built two of the

owners, in order to control the gates at the storage reservoir, bought out the other five owners. When it came to the matter of deciding on the building of the new storage reservoir the seven mill owners were all called upon to take each one seventh of the stock. The five who had sold out declined to take, saying to the other two, "You are the Farmington River Power Company; you control the stock of the company and the stream"; so, of course, the second reservoir was not built. I mention this instance to show the difficulties of handling such partnership matters in the control of reservoirs.

MR. HORTON (*by letter*). Since this paper was prepared, I have been informed that an additional case of compensation in kind exists in New Jersey. Unfortunately, the details are not available further than that a system of compensation was established many years ago in connection with the taking of water from a lake or stream for the supply of navigable canals.

PROCEEDINGS.

June Outing.

Plymouth, Mass., June 24, 1908.

The June meeting of the New England Water Works Association was held at Plymouth, Mass., on Wednesday, June 24, 1908, with the following attendance:

Members.

S. A. Agnew, R. W. Bagnell, Lewis M. Bancroft, Joseph E. Beals, Arthur E. Blackmer, James W. Blackmer, James Burnie, Charles E. Childs, John W. Churchill, Frank L. Clapp, R. C. P. Coggeshall, Michael F. Collins, George E. Crowell, John C. De Mello, Jr., Edward D. Eldredge, Charles R. Felton, John N. Ferguson, Arthur N. French, Albert S. Glover, Frank H. Gunther, Frank E. Hall, Horace G. Holden, Willard Kent, George A. King, A. R. McCallum, Hugh McLean, A. E. Martin, John Mayo, Leonard Metcalf, Frank L. Northrop, J. K. Nye, Oren E. Parks, William H. Pitman, Leonard C. Robinson, Henry W. Sanderson, A. L. Sawyer, Walter H. Sears, Edward M. Shedd, Charles W. Sherman, William E. Smith, Harry L. Thomas, Robert J. Thomas, William H. Thomas, James L. Tighe, D. N. Tower, Charles K. Walker, Lettice R. Washburn, Robert S. Weston, John C. Whitney, L. J. Wilber, George E. Winslow. — 51.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edward F. Hughes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by Edw. M. Shedd; Union Water Meter Company, by F. L. Northrop. — 15.

Guests.

M. M. Garvey, Lawrence, Mass.; Miss Henrietta C. Walker, Manchester, N. H.; Mrs. A. S. Glover, Newton, Mass.; Mrs. F. H. Gunther, Dracut, Mass.; S. M. Spencer, Malden, Mass.; Mrs. Geo. E. Winslow, Waltham. Mass.;

THE SURVIVING CHARTER MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

(From a photograph taken at Plymouth, Mass., June 24, 1908.)

H. G. HOLDEN. R. W. BAGNELL. C. K. WALKER.
F. E. HALL. A. S. GLOVER. R. C. P. COGGESHALL.

I. M. Low, superintendent, Weymouth, Mass.; Mrs. J. N. Ferguson, Boston, Mass.; Miss Nellie Collins, Lawrence, Mass.; Mrs. L. J. Wilber, Brockton, Mass.; Mrs. F. N. Connet, Providence, R. I.; Mrs. A. E. Blackmer, Plymouth, Mass.; Mrs. Walter H. Sears, New York, N. Y. — 13.

[Names counted twice — 3.]

A business meeting was held at the Armory, where the Association was welcomed by representatives of the town, and the following were admitted to membership:

Dana M. Wood, assistant engineer, United States Geological Survey, Boston, Mass.; Frank A. Marston, civil engineer, with Metcalf & Eddy, Boston, Mass.; H. Lester Newhall, third assistant, city engineering department, Brockton, Mass.; Ira C. Forbes, mechanical engineer, West Shokan, N. Y.; Thomas Gray, manager High Falls Power Company, Ellenville, N. Y.; James F. Sanborn, assistant engineer, New York Board of Water Supply, 236 Main Street, Poughkeepsie, N. Y.; Nicholas S. Hill, Jr., consulting engineer, 100 William Street, New York City; Charles L. B. Anderson, consulting municipal engineer, Atlanta, Ga.; C. Sherman Rex, Jr., superintendent Creston Water Works Company, Creston, Ia.; Francis C. Hersey, Jr., water commissioner, Wellesley, Mass.; and Henry A. Young, chief engineer Camaguey Water Works, Camaguey, Cuba.

Most of the members then proceeded to the shop of the Plymouth Water Works on Howland Street, where the construction of the Phipps cement-lined and jacketed pipe, which is exclusively used in Plymouth, was witnessed, and the process was fully explained by Supt. A. E. Blackmer.

Pilgrim Hall and other places of interest were visited by a number of the party. Special electric cars were then taken to Hotel Pilgrim, where luncheon was served and where a photograph was taken of the surviving charter members of the Association, Messrs. H. G. Holden, R. A. Bagnell, Charles K. Walker, Frank E. Hall, A. S. Glover, and R. C. P. Coggeshall. [This photograph is reproduced herewith.] Many of the party then visited the water works pumping station and inspected the work of laying the cement-lined pipe, which was in progress near by.

Twenty-Seventh Annual Convention, Atlantic City, N. J., September 23, 24, and 25, 1908.

The Twenty-Seventh Annual Convention of the New England Water Works Association was held at Atlantic City, N. J., on September 23, 24, and 25, 1908. The headquarters of the Association were at the Traymore Hotel, and the meetings were held in the Assembly Hall at the hotel.

The following members and guests were in attendance:

Members.

S. A. Agnew, Kenneth Allen, M. N. Baker, C. H. Baldwin, A. F. Ballou, F. A. Barbour, G. W. Batchelder, E. W. Bemis, C. R. Bettes, F. E. Bisbee, James Burnie, T. J. Carmody, C. E. Chandler, J. H. Child, C. E. Childs, W. F. Codd, W. R. Conard, G. K. Crandall, John Doyle, M. J. Doyle, E. D. Eldredge, G. H. Felix, B. R. Felton, J. H. Flynn, Murray Forbes, F. L. Fuller, W. B. Fuller, A. S. Glover, Wallace Greenalch, C. A. Hague, F. E. Hall, W. C. Hawley, Allen Hazen, G. T. Ingersoll, G. G. Kennedy, E. W. Kent, Willard Kent, G. A. King, J. J. Kirkpatrick, Morris Knowles, B. C. Little, E. E. Lochridge, F. H. Luce, F. A. McInnes, T. H. McKenzie, Hugh McLean, P. A. Maignen, A. E. Martin, G. F. Merrill, Leonard Metcalf, F. L. Northrop, H. N. Parker, E. M. Peck, E. L. Peene, T. A. Peirce, E. A. Pickup, A. A. Reimer, P. R. Sanders, W. J. Sando, A. L. Sawyer, E. M. Shedd, P. S. Smith, J. F. Sprenkel, L. A. Taylor, R. J. Thomas, J. L. Tighe, D. N. Tower, J. C. Trautwine, Jr., L. L. Tribus, J. H. Walsh, C. S. Warde, J. S. Warde, R. S. Weston, I. S. Wood, C. L. Wooding, Timothy Woodruff. — 76.

Honorary Member.

F. W. Shepperd. — 1.

Associates.

Allis-Chalmers Company, by W. J. Sando; Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters and E. C. Atkins; Central Foundry Company, by J. H. Morrison; Chapman Valve Manufacturing Company, by Edward F. Hughes; The Fairbanks Company, by C. H. White, West DeHaven, and J. F. O'Brien; Hays Manufacturing Company, by T. J. Nagle and C. A. Eaton; Hersey Manufacturing Company, by Albert S. Glover, H. D. Winton, W. C. Sherwood, and W. T. Kershaw; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell, F. B. Mueller, O. B. Mueller, and F. W.

Cruckshank; National Meter Company, by C. H. Baldwin, John C. Kelley, W. P. Oliver, J. G. Lufkin, and Lewis H. Nash; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by H. H. Kinsey, F. A. Smith, and C. A. Vaughan; Norwood Engineering Company, by H. W. Hosford; The Pitometer Company, by L. B. Shoemacher; Pittsburg Meter Company, by F. L. Northrop, T. C. Clifford, A. G. Holmes, and V. E. Arnold; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by Wm. Ross and Adam Ross, 2d; A. P. Smith Manufacturing Company, by F. N. Whitcomb and John W. Strachbeim; Thomson Meter Company, by E. M. Shedd, S. D. Higley, W. S. Cetti, and J. L. Atwell; Union Water Meter Company, by F. E. Hall; United States Cast Iron Pipe & Foundry Company, by F. W. Nevins and W. B. Franklin; Water Works Equipment Company, by Walter H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Company, by Wm. P. Brew and Edward J. Lane. — 55.

GUESTS.

Joseph F. Biladeau, Pittsfield, Mass.; Mrs. Louis L. Tribus, Master Lucian Hall Tribus, Mrs. A. A. Knudson, Mrs. Fred A. Smith, Miss Bessie J. Warde, Mrs. Charles H. White, Mrs. Kenneth Allen, Miss Mildred Arnold, Mrs. F. W. Shepperd, Mrs. J. F. O'Brien, Miss Zada O'Brien, F. W. Stodder, Mr. Thomas Liston, Mr. I. S. Holbrook, Miss Leda Mueller, Mrs. F. W. Cruckshank, Mrs. H. Mueller, Mrs. Edmunds, Mrs. John C. Kelley, Miss Kelley, New York City; Mrs. A. E. Martin, Mrs. Clara A. Kilburn, Mrs. E. E. Lochridge, Springfield, Mass.; Mr. and Mrs. L. Van Gilder, Mr. Wm. H. Randolph, Miss T. Strauss, Mr. Stanley Johnson, Mrs. M. Somers, Miss S. Tilton, Miss Elsie Reuscher, Mrs. H. H. Decker, B. F. Souder, Miss C. May Chase, Atlantic City, N. J.; Mrs. T. A. Peirce, Mrs. Joseph W. Vaughan, East Greenwich, R. I.; Mrs. Francis H. Luce, Woodhaven, N. Y.; Mr. Albert Blauvelt, Chicago, Ill.; Mrs. A. A. Reimer, East Orange, N. J.; Mrs. E. C. Atkins, Mrs. I. S. Wood, Providence, R. I.; Mrs. John Doyle, Worcester, Mass.; Miss A. E. Nugent, Mrs. Albert S. Glover, Mrs. H. F. Gould, Mrs. John H. Flynn, Boston, Mass.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; Mr. M. J. Gray, Burlington, N. J.; Mr. James G. Hill, Mr. Patrick Kelley, Mrs. R. J. Thomas, Miss Katherine Walsh, Miss Charlotte Walsh, Lowell, Mass.; Hon. Horace S. Van Worst, Charles B. Pond, Schenectady, N. Y.; Mrs. John C. Trautwine, Jr., Mr. Joseph Thompson, Mr. George Costello, Mr. W. F. McCarthy, Philadelphia, Penn.; Mrs. Edward L. Peene, Yonkers, N. Y.; Mrs. T. C. Clifford, Miss Lois I. Clifford, Pittsburg, Penn.; Mrs. Murray Forbes, Greensburg, Penn.; Mrs. George H. Felix, Reading, Penn.; Mrs. George G. Kennedy, Harrisburg, Penn.; Mr. W. F. Penn and Miss Katherine Penn, Morganza, Penn.; Mr. Edmund T. Scott, Trenton, N. J.; Miss May I. Agnew, Mr. John J. Heavey, J. W. Griffin, Thomas Rooney, Hon. H. O. Wittpenn, Alex S. Hanult, and Edward W. Henry, Jersey City, N. J.; Mr. Frank S. Fithean, Camden, N. J.; Mrs. Small, Auburn, Me.; Miss Helen C. Doorty, Buffalo, N. Y.; Miss Mary A. Sargent, Cleveland, O.; Mr. R. W. Pratt, Columbus, O.; Miss Grace Merritt, San Fran-

cisco, Cal.; Mr. T. A. Collins, Lawrence, Mass.; Mrs. T. J. Carmody and Mrs. J. J. Kirkpatrick, Holyoke, Mass.; Mrs. Wm. F. Codd, Nantucket, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. F. A. McInnes and Miss Frances McInnes, Boston, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. R. S. Kellogg, Mr. Alvan Donnan, Washington, D. C.; Mr. Frank Little, Mrs. David Little, Rochester, N. Y.; Mrs. O. B. Mueller, New Rochelle, N. Y.; Mr. John K. Guinn, Utica, N. Y.; Mrs. Charles R. Bettes, Far Rockaway, N. Y.; Mr. F. J. Deutschbeim, Albany, N. Y.; Mr. H. R. Beebe, Utica, N. Y.; Mr. T. D. Faulks, Newark, N. J.; Mr. and Mrs. Jas. Donovan, Middletown, Conn.; Mrs. Charles E. Chandler, Norwich, Conn.; Mr. Albert S. Sessions, Bristol, Conn.; Mr. Robert W. Grant, Woonsocket, R. I.; Mr. Peter J. Ford, Dr. A. Robin, Mr. John Keule, Wilmington, Del.; Mr. F. E. Puffer, New York City; Mr. and Mrs. James J. Griffin, Middletown, Conn.; Mr. Arthur W. Burnie, Biddeford, Me. — 113.

[Names counted twice — 6.]

MORNING SESSION, WEDNESDAY, SEPTEMBER 23.

President A. E. Martin called the convention to order and spoke as follows:

Gentlemen of the New England Water Works Association and Guests, — It is hardly necessary for me to reiterate my statement of last January that I am proud to stand before you to-day as president of this Association, which includes among its members men of marked and proven ability in the profession of water-works construction and maintenance, men who are willing to give deep study and much time to the different subjects in which we are interested, and then bring before us, in well-written papers, ideas which benefit us all.

Many of those who organized this society have joined the silent majority, and their faces are much missed at our conventions, but the same spirit is manifest to-day that was shown twenty-seven years ago, when that little body of men first associated themselves together for mutual help and improvement.

I am pleased to greet you in Atlantic City to-day. For a long time many of our members have desired to hold a convention in this city, and to-day we see the fruition of those wishes.

To me it is somewhat of a red-letter day in another way, for besides being the opening day of this convention of our Association, it also marks the beginning of another lap on my life's journey. Something more than *twenty-seven* years ago, on the

twenty-third of September, in an old red brick farmhouse in the good old town of Brooklyn, Conn. (that land of steady habits and wooden nutmegs), at very early hour in the morning (so I am credibly informed), the interesting event occurred which made it possible for me to stand here to-day as your presiding officer.

I feel that I must digress here to say that my enforced early rising on that eventful morning undoubtedly prejudiced me against the practice ever after, for it has been only with a most unwilling spirit that I have ever indulged in such a luxury since.

But laying all jesting aside, it will always be one of the pleasantest incidents of my life that on this anniversary I had the pleasure and honor of presiding at the twenty-seventh annual convention of the New England Water Works Association.

I will not take up more of your time, for I know you are all anxious to hear another who is present and who, doubtless, considers it a pleasure as well as a privilege to greet you.

I take great pleasure in introducing his honor, Mayor Stowe, who will give you a welcome to this fair city by the sea.

MAYOR STOWE. *Mr. President and Members of the Association,* — I assure you that it gives me great pleasure to come before you this morning, and I wish particularly to congratulate the President on his birthday. It must be very pleasant for him, especially if he has his family with him, and I hope that at least once in twenty-seven years they can all have a day of recreation at the seaside. I understand this is the first time that your Association has ever met in our city. I am surprised that a matter so important to you and to us has been left so long unattended to. [Laughter.] You gentlemen are engaged in an occupation for the benefit of humanity, and you should be looked up to with more appreciation, perhaps, than any of the rest of us who are engaged in municipal affairs, for it is your particular duty to see to it that we have good water. It has been my privilege during the past few years to appoint the water commissioners of our city, and I can say that for eight or nine years we have had a very efficient board. As you know, here on the seashore we cannot get our water from driven wells, and there is no fresh water stream, and we are compelled to go to the main land for our supply. I can assure you that you can drink our water here with the certainty that you are drinking

something that cannot be equaled in the shape of water within a radius of at least two or three hundred miles.

We are proud to have you with us, and we hope to receive much benefit from your visit. We bid you welcome and extend to you the freedom of the city. I trust that you will feel at liberty to make all the investigation and inquiry into our affairs — to " butt in," if you please — that you desire; and we will be ready to listen and learn anything you can tell us which will better our condition, for certainly this body must possess a great deal of valuable information on the subject of water supply.

Now, Mr. President, as you know, our city is going through a rather strenuous ordeal in certain directions [laughter], and as I was not able to get to bed at all last night, I trust you will excuse me from making any further remarks. I will, therefore, close by repeating that I want you to feel free to do just as you please here, to feel that you belong to us as long as you stay here, and if I can be of any service to you at all I shall be only too happy. I thank you for this opportunity to speak to you. [Applause.]

THE PRESIDENT. I can assure you, Mr. Mayor, that the Association appreciates your welcome and will be glad to accept your courtesies.

On motion of Mr. George A. King, it was voted that the President be authorized to appoint a committee of five to nominate officers for the ensuing year. The following-named gentlemen were appointed as the committee: J. C. Whitney, Newton, Mass.; Leonard Metcalf, Boston, Mass.; George A. Stacy, Marlborough, Mass.; E. W. Kent, Woonsocket, R. I.; William F. Sullivan, Nashua, N. H.

Mr. John C. Trautwine, Jr., civil engineer, Philadelphia, Penn., read a paper on " Water Purification at Philadelphia," illustrated by lantern slides.

Adjourned.

AFTERNOON SESSION, WEDNESDAY, SEPTEMBER 23.

President Martin in the chair.

The afternoon session was devoted to a consideration of the subject of the conservation of the natural resources of the

country. The first item of the program was the report of the committee on this subject, and the president called upon Mr. M. N. Baker, who said:

"This committee was appointed a few months ago to take up the important question of the conservation of the natural resources of the country. It has seemed best to bring the subject before the convention in the form of papers by experts on those phases of it most important to our members. It was the intention to have papers on forestry, on water supply, and on coal. Unfortunately we were unable to secure a paper on coal; those on water supply and forestry will now be presented."

The first paper, entitled, "The Conservation of Water Resources," by Marshall O. Leighton, chief hydrographer, United States Geological Survey, Washington, D. C., was read by Mr. Horatio N. Parker."

An address on "Forestry," by R. S. Kellogg, of the United States Forest Service, Washington, D. C., followed, and the subject was discussed by Messrs. P. A. Maignen, Robert S. Weston, Allen Hazen, Frank L. Fuller, W. C. Hawley, Albert Blauvelt, M. N. Baker, H. N. Parker, Edward W. Bemis, George A. King, and A. A. Reimer. At the conclusion of the discussion President Martin said:

"Are we to understand that the committee is to be continued, and that we may have the pleasure of hearing something more from it in the future? This is a very important question and should be kept alive before the Association."

Mr. Baker. As I remember it, the appointment of the committee was at the suggestion of the Executive Committee of the Association because the subject was at the front, and the four leading national engineering societies had already appointed committees on the conservation of the natural resources of the country. What the pleasure of the Association may be as to continuing our committee I, of course, do not know.

The President. Unless there is objection on the part of any of the members, this report will be received as a report of progress and the committee continued for further work. There being no objection to that it will be so understood.

Adjourned.

MORNING SESSION, THURSDAY, SEPTEMBER 24.

President Martin in the chair.

The Committee on Standard Specifications for Fire Hydrants presented the following report of progress:

BOSTON, MASS., September 17, 1908.

To the New England Water Works Association, — The committee appointed to prepare specifications for street hydrants has had two meetings, an afternoon having been devoted to each, with the result that a general outline of specifications has been prepared, but we have not been able to get this into proper shape for presentation to the convention next week. We, therefore, can only report progress at the present time, with the expectation of submitting a little later to the Association a specification in reasonably complete form.

H. O. LACOUNT, *Chairman.*

The first paper on the program for the morning was a "History of the Haverhill Water Works," by Albert A. Sawyer, water registrar, Haverhill, Mass. Its reading was supplemented by some general observations by Mr. M. N. Baker on the importance of the preservation of historical data in connection with water works.

Mr. R. S. Weston, sanitary expert, Boston, Mass., read a paper on "Rubber Pipe Joints." The subject was discussed by Mr. Allen Hazen, Professor Bemis, Mr. W. C. Hawley, Mr. Van Gilder, and Mr. Charles E. Chandler.

Mr. Frank L. Fuller, civil engineer, Boston, Mass., submitted a paper entitled "Covered Reservoirs; Some Experience in the Use of Concrete in their Construction and in making them Water-tight." Following the reading of the paper Mr. Fuller showed a large number of lantern slides illustrating his subject, and the exhibition of those closed the morning session.

AFTERNOON SESSION, THURSDAY, SEPTEMBER 24.

President Martin in the chair.

The first paper of the afternoon was presented by Mr. Ermon M. Peck, distribution engineer, Hartford, Conn., his subject being "Meters and Water Consumption of the Hartford Water Works." Messrs. Allen Hazen, M. N. Baker, and H. N. Parker took part in the discussion.

A paper on "Meter Rates," by W. H. Richards, engineer and superintendent, New London, Conn., was read by Mr. George A. King. It was discussed by Prof. Bemis and Messrs. W. C. Hawley, A. A. Reimer, Hugh McLean, Albert Blauvelt, Leonard Metcalf, Frank L. Fuller, H. N. Parker, and J. H. Child.

Mr. Frank A. Barbour, civil engineer, Boston, Mass., presented a paper entitled, "The Water Service and Insurance Rates." Mr. Charles E. Chandler, Mr. Allen Hazen, and Mr. Leonard Metcalf took part in the discussion.

The regular program for the afternoon having been concluded, the President announced that Mr. Metcalf had in mind a matter which he desired to call to the attention of the convention.

Depth of Laying Water Pipes.

Mr. Leonard Metcalf. There is a matter which I should like to bring before the Association, which it has seemed to me might furnish an interesting subject for investigation. Some time ago it occurred to me that we had very little tangible or valuable information concerning the desirable depth at which water pipes should be laid in different latitudes and under different conditions, and I set out to prepare, and did prepare, a schedule of questions which I purposed sending to different water-works departments, in the hope of getting some light on this question, and getting some statistics in regard to actual experience with frozen pipes. Then it occurred to me that greater weight would be given to the investigation, and perhaps there might be a readier response to inquiries, if the work were undertaken by the Association, particularly in the light of the admirable work which some of our committees have done. So I thought of making a motion at this time, that a committee of seven, or whatever number might seem desirable to you, be appointed to gather statistics relating to the depth at which water pipes are laid, and the resulting experience with frozen pipes, not only in New England, but in different parts of the country if the scope of the inquiry could be successfully extended.

In going over this matter, I discussed the question with some friends, and wrote one or two letters which drew forth some very

pertinent suggestions, it seemed to me, and those I should be very glad to turn over to the committee should it seem desirable to you to appoint such a committee.

It seems to me it is not sufficient to inquire simply as to the depth at which pipes are laid in different works, and the character of the material in which they are laid, but that we should go further and inquire particularly into the cases that have arisen of frozen pipes, covering in our inquiry, aside from the elements which I have mentioned, that perhaps most important of all, the consumption of water through those very pipes. It is only from experiences of that sort, I believe, we can get the definite, tangible information that we need.

The President. Do I understand you make that motion?

Mr. Metcalf. I make that motion, Mr. President.

Mr. Hazen. I second the motion, Mr. President. I have been greatly impressed at times, in walking over pipe lines and examining them, to observe that they were very much nearer the surface of the ground than common practice would seem to justify, and nevertheless they have not frozen; and I have wondered whether it was really safe to put pipes so near the surface as that, and, if so, if we were not wasting lots of money in putting them deeper.

Mr. H. N. Parker. It seems to me this would be a very valuable inquiry, but I think to the duty of that committee should be added that of collecting data in regard to the size of pipe and length of pipe that may safely be exposed in going over bridges, etc., without danger of freezing. That is a question I have often heard brought up, and it seems to me a very practical question for many superintendents, if they have a line of pipe crossing a ravine or a bridge, — whether it is necessary to cover it. I would have that included in the investigation.

Mr. Metcalf. In that connection, Mr. President, it might also be interesting, in order that it may be a matter of record here, to suggest that there has doubtless been experience with penstocks which will furnish very interesting data on that line. I know one came to my attention up in Maine which, I think, was 4 feet in diameter and absolutely exposed, and which lay idle for certain hours in the day, and in which they prevented freezing by partly

opening a small gate,— I think it was something like three or four inches, — and they had no trouble from freezing or anchor ice.

THE PRESIDENT. I would like to ask Mr. Metcalf if he has his motion in writing, or, if not, if he will put it in writing so that it can be acted on.

MR. METCALF. The gist of the motion is that a committee be appointed to gather statistics relating to the depth at which pipes are laid and the resulting experience with frozen pipes.

THE PRESIDENT. And would you like to add Mr. Parker's suggestion?

MR. METCALF. I would be very glad to incorporate that. I did not wish in any way to limit the scope of inquiry of the committee.

MR. W. C. HAWLEY. I would suggest in connection with the investigation that the temperature of the water that is passing through the pipe is quite an important factor, and I suppose of course that will be considered.

THE PRESIDENT. These items, perhaps, might be brought out in the questions which will be sent out by the committee.

MR. METCALF. If there is no objection, Mr. President, I will furnish the schedule of questions as I had arranged them myself, in order that they may be a permanent matter of record, not in any way to limit the action of the committee, but simply for the use of the committee, leaving the committee entirely free to modify, extend, or cut out any questions they may wish.

(The motion that a committee be appointed was adopted.)

MR. ALLEN HAZEN. I am going to suggest, Mr. President, as one member of the committee, a member of the Association who is not here, Mr. Kuichling. I happen to know he has made many calculations along this line, especially along the line of Mr. Parker's suggestion in regard to exposed pipe.

THE PRESIDENT. I will take the matter into consideration and announce the committee at the beginning of the evening session.

(The President subsequently appointed as the committee Messrs. Frank A. Barbour, Boston; R. S. Lea, Montreal, Canada; W. C. Hawley, Wilkinsburg, Penn.; R. Winthrop Platt, Columbus, Ohio; Emil Kuichling, New York City; W. C. Hoad, Lawrence, Kan., and Dabney H. Maury, Peoria, Ill.)

(The following correspondence and schedule of questions sug-

gested for the consideration of the committee were submitted by Mr. Metcalf.)

NOVEMBER 6, 1907.

MR. LEONARD METCALF, BOSTON, MASS.

Dear Mr. Metcalf, — I am much interested in your proposed collection of data regarding the depth of water pipes. I regard the inquiry as a most important one.

I see your schedule is arranged to take into account most of the points that I should be interested in, and I will only make some very general suggestions regarding it. I have not studied it as carefully as I would do if I had more time before leaving for the West, so what I say may duplicate what you already have.

In the first place, I would try to get the data relating to the particular mains which are frozen, and make this point very clear so that those who fill out your blanks will not give you the depths, materials, etc., that are generally used. It seems to me that the inquiry will be much more valuable to limit it strictly to those places where trouble has actually been experienced.

Limiting it in this way to those points, I should be especially interested to know the size of pipe; the depth; the character of the soil, especially whether clayey and impervious or gravelly and pervious; and the height of the ground water, if any, over the pipe. These matters I believe are all indicated on your schedule.

I should also want to know especially the length of pipe so exposed, if the location was specially exposed, and I should want to know as to the flow of water through the pipe, whether it was rapid or slow, continuous or intermittent. These are very hard matters to tabulate, but it would seem to me that they are likely to be of controlling importance in this matter.

I would also suggest that you make a special study to see if there has been any reduction in carrying capacity of pipes in exposed positions during continued severe winter weather. I have been especially interested in the last years in seeing a number of important leading-mains supplying cities running for miles with but little covering. Last week I walked over a mile of pipe that did not have over six inches of cover, much of the way the bells of the pipe being exposed, and here and there whole lengths of pipe. This pipe has been in use some years and there has been no reason to think that it has ever given trouble from freezing.

Now it would seem to me that in very cold weather anchor-ice would form on the top and sides of this pipe and reduce the carrying capacity. I believe that it is common experience for the penstocks and draft tubes of water-power plants, which are commonly exposed, to have their carrying capacity reduced in this way, and

it would seem to me that some of these leading-mains would show a corresponding reduction in carrying capacity. So long as there was no necessity for using the main to the limit of its capacity at these times, this reduction in carrying capacity very likely would not be noticed, but it does seem to me that it would be likely to occur and that its occurrence would be a matter of great importance, which would necessarily have to be taken into account in making adequate calculations. This is the more important because the maximum use of water often comes at times of continued severe cold weather.

Hoping that these rough suggestions will be of some use to you, and assuring you that I shall be very glad to see the compilation of your data when it is ready, I am,

Very truly yours,

ALLEN HAZEN.

The President presented Mr. Albert Blauvelt, associate manager of the Western Factory Association, Chicago, Ill., who desired the privilege of the floor to make a statement.

MR. ALBERT BLAUVELT. Mr. President, my statement will be very brief. The National Fire Protection Association have a standing committee on pipe, of which I am chairman, and I have come to this meeting in the hope of meeting those of your members who are most informed on the subject of cast-iron pipe. It transpires that some of them, at least, are not present at this meeting, and therefore such information as I shall need in the discharge of my duty will have to be obtained at some succeeding meeting.

The National Fire Protection Association is desirous of adopting a standard for pipe, and it appears that there are two or three printed specifications in the field. I simply rise to have it made a matter of record that I have discharged my duty in putting in a representation here, and I hope it will be the feeling among you individually that in the course of two years or three years or four years or five years, or whatever time is necessary, the discrepancies in pipe specifications can be eliminated and a uniform specification arrived at. One reason for my presence here is that the National Fire Protection Association is in touch with the International Association, and we had very much rather have uniform specifications in this country before taking up any question of standards with the Europeans.

[*Inquiries suggested by Mr. Metcalf.*]

WATER WORKS.—STATISTICS RELATING TO DEPTH OF LAYING PIPES.

Date of Reply________ Name________ Official Position________

________Water Works City or Town________ State________
(Municipal or Company Works. Give name if latter)

Distance of City from Ocean____ miles
Mean Temperature, Deg. F.____ °
Character of Supply________
(Gravity or Pumping Supply)

Elevation above Sea____ feet
Extreme Winter Temperatures____ °
Hours of Pumping daily________
(24 hours or how many)

Approx. minimum hourly rate of pumpage during winter months________
,, mean daily water pumpage during winter months________

	Range of Diameters.	Approx. Length Miles.	Kinds.	Feet Depth of Laying to			Pipe laid by Contract or by the Company.
				Axis of Pipe.	Bottom of Trench.	Cover over Pipe.	
Supply Mains Distribution Mains Service Pipes							

	* Kind or Character of Soil.	Depth of Frost in Feet in Streets or Highways.		Depth of Frost in Feet in Fields, or Outside of Streets and Highways.
		General.	Extreme.	
Supply Mains Distribution Mains Service Pipes				

* Note: Rock, Hardpan, Clay, Sand or Gravel, Alluvial, mixed.

Approx. percentage in length of pipes below level of ground water—— ——%. Are water pipes laid at stated depth for other reasons than danger of freezing? If so, for what reasons?——————————

If records have been kept of frozen pipes, kindly quote or abstract them below in the column of remarks, and fill in the following table, if possible :

	Winter of 1904–5.	Winter of 1905–6.	Winter of 1906–7.	Worst Winter in Recollection of Oldest Inhabitant.
Number of cases of frozen supply mains				
" " " " " distrib. "				
" " " " " service pipes				
Total length of feet of frozen supply mains				
" " " " " " distrib. "				
" " " " " " service pipes				

Is town or city sewered?. ——— (Yes or No.) Name——————————

I also wish to express the hope that the New England Water Works Association will become an active and voting member of the National Fire Protection Association, and that you will send us a voting delegate. That is being done now by a great many associations who are engaged in matters pertaining to construction or equipment in any way allied to fire protection. I thank you for your attention. [Applause.]

Adjourned.

Evening Session, Thursday, September 24.

President Martin in the chair.

The Secretary read the following names of applicants for membership, all properly endorsed and recommended by the Executive Committee:

Active. — Gilbert C. White, Durham, N. C., consulting hydraulic engineer; Albert L. Sessions, Bristol, Conn., president of the Bristol Water Company; Edwin L. Stone, Winchendon, Mass., engaged with the Winchendon Water Works; Albert Blauvelt, Chicago, Ill., associate manager Western Factory Association; Arthur L. Adams, Oakland, Cal., hydraulic engineer; H. J. Deutschbein, Albany, N. Y., superintendent Albany Water Works; W. C. Hoad, Lawrence, Kan., sanitary engineer, Kansas State Board of Health; R. Winthrop Pratt, Columbus, Ohio, chief engineer, Ohio State Board of Health; John S. Keinle, Wilmington Del., chief engineer Wilmington Water Company.

Associate. — East Jersey Pipe Company, New York, manufacturers of lock bar steel pipes and riveted steel pipes.

On motion of Mr. H. N. Parker the Secretary was directed to cast one ballot in favor of the election of the candidates whose names had been read, and, he having done so, they were declared duly elected members of the Association.

Mr. Leonard Metcalf, secretary of the Committee on Awards that have been made for Damages resulting from the Diversion of Water, reported progress for the committee as follows:

Progress Report of Committee on Awards that have been made for Damages resulting from the Diversion of Water.

Under a vote passed by this Association at its last annual con-

vention, held in Springfield, Mass., on September 12, 1907, the sub-joined committee of five was appointed by the President

"To collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers Association, or other organizations of mill owners, relating to the formation of standard rules for computing or assessing damages for the diversion of water."

Your committee has succeeded already in getting together a considerable amount of available data relating to water and water-power diversion suits, but it has seemed desirable to it, in order to broaden the scope of its work and to bring together as far as possible all available material, to send out a postal card inquiry to the members of this Association, as was recently done, asking members to contribute memoranda of any data or cases with which they might happen to be personally familiar, bearing upon the investigation under question, which they might be willing to place at the disposal of the committee. In this way, your committee hopes to acquire data relating to the valuations, sales, or awards for water or water-power diverted under right of eminent domain, of which it might otherwise fail to learn, and incidentally to prevent duplication of information and useless work on the part of active members of the Association in preparing the data. This card of inquiry was sent out with the last notices for this convention, and your committee is glad to be able to report that already a considerable number of encouraging replies have been received. Members who have not yet replied to the circular are urged to do so, in the interest of the Association and in the hope of broadening the scope of the inquiry as far as possible.

Your committee now has under advisement a general set of questions to be forwarded to members who have information along these lines, and have responded favorably to the earlier inquiry of the committee, to assist in the preparation and assembling of the facts in as concise and comparable form as possible. The proposed schedule now under consideration is submitted for friendly suggestion and criticism.

OUTLINE OF PROPOSED SCHEDULE OF QUESTIONS RELATING TO WATER AND WATER-POWER DIVERSION DATA, TO BE SENT TO MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

1. Data of valuation, sale, or award.
2. Amount thereof, exclusive of interest ($).
3. Total amount, including interest and allowances for collateral items.
4. Incorporated name of both parties.
5. Location, town, city, county, and state.
6. Character of privilege.
7. Total area of watershed taken or diverted.
8. Amount of watershed taken or diverted.
9. Amount of water taken or diverted.
10. Theoretical fall taken to which right was claimed.
11. Fall used or developed.
12. Hours per day during which power is used.

In addition to the above fundamental or elementary questions the following questions which will throw valuable light upon the information given will probably be appended in a separate group·

13. Character of development, product of mill, etc.
14. Character of watershed.
15. Cost of coal per 2 000 pounds and of electric current.
16. Is steam used for manufacturing or other purposes?
17. Is water used for any other purposes than for power?
18. Number of wheels installed.
19. Power of wheels.
20. Total steam and electric power development.
21. Total power required to run mill.
22. If supplementary steam or electricity is necessary, state amount.
23. What must be done to improve the privilege, or to develop undeveloped available power there, and cost thereof.
24. Approximate area of mill pond.
25. Approximate depth to which mill pond can be drained.
26. Are there other storage reservoirs upon the watershed? If so, state capacity.
27. Character of control of the storage.
28. What were the controlling factors in the award?
29. Did the award include any allowances other than for the water or water-power?

It has further seemed probable to your committee that for purposes of general standardization or comparison, so far as this

may prove feasible or desirable, the units of value or award in "$—— per square mile of watershed per foot of fall" and the "number of daily million gallons of water diverted per foot of fall," would prove the most satisfactory.

Acting upon the latter part of the vote under which your committee was appointed, after careful consideration of the subject, the conclusion was reached that it is impracticable for the committee "to formulate standard rules for computing and assessing damages for the diversion of water." The committee, with the exception of certain of its members, who modestly refrain from referring to their own work, though hoping to present later a bibliography of the subject, now recalls to the attention of the members of this Association the papers upon this subject published in the JOURNAL of this Association in September, 1907, p. 214 *et seq.*, which in its opinion furnish the best guide to the engineer in methods of computing and assessing damages for the diversion of water, but the committee recognizes that the question is one of law rather than of engineering practice, and that every suit is likely to involve some novel features, and must of course be considered in the light of local circumstances and conditions.

Recognizing the necessity and importance of the subject to the members of this Associaton and the fact that work has but just begun, your committee presents this progress report and asks to be continued.

Respectfully submitted,

CHARLES T. MAIN, *Chairman.*
CHARLES E. CHANDLER.
RICHARD A. HALE.
WILLIAM WHEELER.
LEONARD METCALF, *Secretary.*

Mr. Charles E. Chandler, civil engineer, Norwich, Conn., read a paper entitled "Stream Flow Data."

Mr. Robert E. Horton, hydraulic engineer, Albany, N. Y., submitted a paper, which was read by Mr. Leonard Metcalf, on "The Adjustment of Damages for Stream Diversion by Storage Compensation." Mr. Louis L. Tribus, Mr. Allen Hazen, Mr. T. H. McKenzie, and Mr. Metcalf spoke on the subject.

Mr. Allen Hazen reported for the Committee on Awards that have been made in Water Works Valuation Cases that the only action taken by the committee up to this time, so far as he knew, had been to elect Mr. Desmond FitzGerald chairman. The report was accepted as a report of progress.

Adjourned.

FRIDAY, SEPTEMBER 25, 1908.

This day was devoted to excursions to points of interest in and near Atlantic City.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at Plymouth, Mass., June 24, 1908.

Present: Messrs. Martin, Collins, Thomas, Bancroft, Sherman, Tower, and Kent.

Eleven applications received and the applicants recommended for membership, viz.:

Dana M. Wood, Frank A. Marston, H. Lester Newhall, Ira C. Forbes, Thomas Gray, James F. Sanborn, Nicholas S. Hill, Jr., Charles L. B. Anderson, C. S. Rex, Jr.,F. C. Hersey, Jr., and Henry A. Young.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association held at Atlantic City, N. J., Thursday, September 24, 1908.

Present: President Alfred E. Martin and members M. N. Baker, George A. King, D. N. Tower, Robert J. Thomas, George W. Batchelder, and Willard Kent.

The following applications were received and approved for membership, viz.:

Gilbert C. White, hydraulic engineer, Durham, N. C.; Albert S. Sessions, president Bristol Water Company, Bristol, Conn.; Edwin L. Stone, Winchendon, Mass.; Albert Blauvelt, associate manager Western Factory Association, Chicago, Ill.; Arthur L. Adams, hydraulic engineer, Oakland, Cal.; H. J. Deutschbeim, superintendent water works, Albany, N. Y.; W. C. Hoad, sanitary engineer, Kansas State of Board Health, Lawrence, Kan.; R. Winthrop Pratt, chief engineer Ohio State Board of Health, Columbus, Ohio; John S. Kieule, chief engineer Water Department, Wilmington, Del.

Associate. — East Jersey Pipe Company, manufacturers of lock bar steel pipe and riveted steel pipe, 90 West Street, New York City.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

GEORGE E. WILDE died very suddenly of heart disease at the office of the Metropolitan Water and Sewerage Board, in Boston, on July 17, 1908. Mr. Wilde was born in Duxbury, Mass., January 29, 1850, and received his early education in an academy in that town. At the age of fourteen he began a seafaring life, which was continued for seventeen years, during which time he made voyages to Spain, Italy, India, Philippine Islands, Germany, Australia, England, and China, and rose from cabin boy to the position of first mate. From 1881 to 1884 he was employed as a foreman in the water department of the city of Worcester, Mass., and during the following six years was employed by A. H. Howland in constructing water-works plants in the middle West. In 1890 he became superintendent of one of these plants at Menominee, Mich., and remained there until 1896, when he returned to Massachusetts and connected himself with the Metropolitan Water Works, the construction of which was then beginning. On December 14, 1897, he was appointed assistant superintendent of the Distribution Department, having charge of the pipe lines and reservoirs of the Metropolitan Water Works within the Metropolitan District, which office he held until his death. He was married in 1879 to Angie C. Joyce, of Duxbury, who, with his son and daughter, survives him. He was elected a member of this Association on June 16, 1886.

IRVING T. FARNHAM, city engineer of Newton, Mass., died September 19, 1908. Mr. Farnham was born in Deposit, N. Y., in 1869. He was graduated from the College of Civil Engineering of Cornell University in 1892. After a few months' service as draftsman for the Elmira Bridge Company, he went to Newton and entered the city engineer's office. He was engaged in im-

portant work for the city until 1899, when he became principal assistant engineer for the Massachusetts Highway Commission. He held this position only about a year, as he became city engineer of Newton in 1900 and remained in that office until his death. During his term of office he had carried out many important pieces of work for the city. He is survived by a wife and four children. Mr. Farnham was a member of the American Society of Civil Engineers and the Boston Society of Civil Engineers. He was elected a member of the New England Water Works Association on December 13, 1905.

BOOK REVIEWS.

Typhoid Fever: Its Causation, Transmission, and Prevention. By George C. Whipple. xxxvi, 408 pages. $5\frac{1}{2}$ x 8 inches. New York: John Wiley & Sons. 1908. Price $3.00.

The author says in his preface: " The object of this book is to furnish to the members of these two professions [physicians and engineers] a condensed summary of the most important facts that have been learned regarding typhoid fever so far as they relate to the prevention and spread of the disease; to furnish to the student of sanitary science a group of illustrations of some of the leading principles of epidemiology; and to give to the general reader a simple and, it is to be hoped, a clear and correct account of the causation, transmission, and prevention of the disease, and his own responsibility in helping to bring about such conditions of cleanliness that typhoid fever shall soon cease to be a national disgrace."

The members of this Association, to which some of the best papers descriptive of typhoid fever epidemics have been presented, should welcome the present volume. Mr. Whipple has long been known to them as an authority in this field, and as a clear and forceful writer. He has succeeded well in his task, and it is much to be desired that every person who has any responsibility for the quality of a water supply should read this book carefully.

The author concludes that in a general way about 40 per cent. of the typhoid fever in the United States is due to infected water, 25 per cent. to milk, 30 per cent. to ordinary contagion (including transmission by flies), and 5 per cent. to other causes. Thus, in spite of the great improvement in the quality of public water supplies that has been made in recent years, water still remains the most important single cause of the spread of typhoid fever, and it behooves all water-works men to have a clear understanding of the subject, not only that they may suitably protect the water supplies committed to their charge, but also to assist them in placing the responsibility for typhoid cases or even epidemics which may be unjustly charged to the water supply.

From the point of view of the sanitary engineer, it is difficult to imagine a question upon typhoid fever which is not answered in this book. It makes no pretense of treating the subject from a medical standpoint, although the symptoms and the bacteriology of the disease are described with some detail, and in the appendices are described the tests of diagnosis, the bacteriology of the blood, and the methods of examination of water for bacillus typhi.

The book is illustrated by a large number of diagrams and contains a number of tables, particularly of populations and typhoid fever death-rates. There is an excellent index.

NOTES ON HYDRO-ELECTRIC DEVELOPMENTS. By Preston Player. 68 pages. 5 x $7\frac{1}{2}$ inches. New York: McGraw Publishing Company. 1908. Price $1.00.

This little book was written primarily for the purpose of presenting a general treatment of the subject set forth in the title, dealing particularly with the commercial side of the matter, in such a manner as to be acceptable to investors, capitalists, and bankers. It is difficult to see how this book can even in slight measure, fulfill the requirement. It is a carelessly written and very poorly edited book. Its treatment of the subject is so "general" as to be decidedly incomplete, yet technical terms are used so freely and with so little explanation of their meaning that it can hardly be intelligible to the classes for whom it was particularly written.

The titles of the chapters are as follows: Preliminary Determinations; Methods of Procedure; Engineering Examination; The Extent of the Market for Energy; Cost of Energy Manufacture; Central Station Economics; Sale of Electric Energy; Primary and Secondary Powers; Capital Costs.

TRADE PUBLICATIONS.

The Thirty-Ninth Street Sewage Pumping Station (Chicago, Ill.). Allis-Chalmers Company, Pumping Engine Department. Bulletin No. 1611, May, 1908.

This bulletin describes the equipment of a sewage pumping station having a capacity of 2 160 000 000 gallons per day, which contains two screw pumps, of the type first used for flushing pumps at Milwaukee, and four vertical centrifugal pumps. The latter are driven by horizontal triple expansion engines, with the cylinders set 120 degrees apart; the screw pumps are driven by vertical triple expansion engines. The boilers, condensers, piping, and coal handling systems are also briefly described

The Manhattan High-Pressure Fire Service System. Allis-Chalmers Company, Pumping Engine Department. Bulletin No. 1614, August, 1908.

This bulletin describes the high-pressure fire system of New York City, about which so much has been said of late. This system consists of main pipes and hydrants independent of the regular water-works system, to which water is furnished under unusually high pressures (300 pounds or more per square inch) by two pumping stations equipped with multi-stage centrifugal pumps, driven by electric motors.

NEW ENGLAND WATER WORKS ASSOCIATION.

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THE CONSERVATION OF WATER RESOURCES.

BY M. O. LEIGHTON, CHIEF HYDROGRAPHER, U. S. GEOLOGICAL SURVEY, WASHINGTON, D.C.

[*Read September 23, 1908.*]

It is extremely difficult, if not impossible, to confine the presentation of this subject to those features relating solely to municipal water works. It is so broad and comprehensive that it does not admit of separation into parts, but each field of application comprehends every other. One, and only one, great problem is involved in the conservation of water resources, and when we attempt to separate the particular province of irrigation from that of flood control, or the field of municipal supply from that of water power, or attempt to legislate, to contrive, or to construct for the benefit of one interest exclusively, we often find that we have wrought to the disadvantage of every other. Every detail in the conservation of water for city supply, for example, should be weighed and considered, not exclusively from the single viewpoint, but with due regard for all allied problems of water utilization. The final wise course to be pursued will be that which will serve the greatest number of objects in the wisest way.

We have made little, if any, progress toward the final development of our river systems. Certain improvements have been made, here and there, directed toward a particular and immediate purpose, such as the creation of a navigable channel or the storage of a municipal supply. Beyond this conditions are chaotic, and mature consideration of the matter will show that the principal reason is, that we have, during past years, endeavored to provide

specifically for one interest to the exclusion of another. What, indeed, has been our practice in the development of rivers for navigation? Our engineers have endeavored to provide channels of stated depth at low-water seasons. No other purpose has been confessed. Our water-supply engineers have endeavored to secure storage capacity sufficient to supply municipalities with all the water required, whether the season's drought be long or short. No other purpose have they had in view. Our water-power engineers have endeavored to so develop certain selected sites that they might be made to produce the greatest amount of available energy, and they have thought of little else. Now, in connection with these several developments, had there been foremost in view the ultimate maximum development of the whole river system for present and immediate uses, as well as for those that are bound to come in the far distant future, there must have been an harmonizing of all the various interests involved, so that each step in the subjugation of the river for one or for another purpose would have become a part, so far as physically possible, of the development of the great unit problem.

In the construction of a building, we consider that each stone laid in the wall is not merely a necessary part of the wall at that immediate point, but is a progressive feature of the whole structure, performing its part in the support of the building, and harmonizing itself with the entire plan. So should be each feature of the development of our water resources, and when this is realized and put into practice, we may consider that we have gone a long way toward the final solution of our problems.

It will now be profitable to consider just what we mean by the water resources of the United States. The first impression conveyed is that of a certain amount of water collected on certain drainage basins and conveyed through certain channels into the ocean, and being made to perform, in transit, certain work of benefit to the people. This is not all. Water is not a resource unless it is available for use, and the conditions under which it is so available determine the amount of resource represented. If the water resources of this country are locked up under conditions of ownership or rental which make them either unavailable, or available only at high cost, the resource represented is far less than would

appear upon first consideration. Therefore, we have to consider the condition of ownership and policy of treatment and retention as well as the amount of water and its potential possibilities.

This matter of ownership is one in which we can hardly find cause for congratulation. The United States was abundantly provided with water resources before the American people set foot on the continent. Therefore, we can gain no credit from the actual possession. We begin to be concerned when we consider our stewardship or our administration of those resources, and just there, at the first point where we must be tested, we begin to fail. It appears that we have omitted no expedient by which they could be wasted and placed beyond our control. We find in the third annual report of the New York State Water Supply Commission the following melancholy statement: "We have only to look across our northern border to the Dominion of Canada to see how our mistakes in allowing private interests to acquire natural resources have been avoided by the statesmanship of the Dominion government." This admission was made by a group of gentlemen who had been at work for a year on investigations necessary to collect information relating to the water powers of the state, and to devise plans for the development of such water powers for public use under state ownership and control. This commission was guided in its work by one of our foremost engineers. The character of the work and the excellence of the report are sufficient assurance that this group of gentlemen weighed its words and we may assume that this commission took no particular gratification in admitting the conditions above quoted. What is true in New York state is also true in greater degree in all of the other states of the Union — certainly in no less degree. Therefore, when we examine our water resources for the purpose of determining upon proper public policies, we find that we are obliged to look across an international border to find that condition which we, ourselves, ought to be able to realize. We have been poor stewards. In the one feature of water conservation in which we, as a people, have absolute control, we have failed.

There are many reasons why we have been lax in our public policy and are now liable to pay the price. Not the least among these reasons is the extremely pronounced tendency of the average

American to secure the highest possible profit during the immediate moment, without regard to future consequences and to the exclusion of every civilized duty to future generations. There is something more to be considered than the present generation. All these resources are merely to be held in trust for the future. The President of the United States was right when he said, " You are a very poor citizen if your interest in general welfare does not extend beyond your own generation."

Another important reason for our lax public policy is our apparent lack of ability or willingness to exercise legislative foresight. If we review the history of water legislation during the past century we will find very few acts deliberately framed to provide for the future. We legislate as a rule "from hand to mouth." When an abuse is discovered, remedial legislation follows. When an emergency arises, acts are passed to meet it. When there is a pressing need, new laws come to the rescue. But it is nearly always evident that the emergency is at hand, the abuse past history, and the need urgent. We find very little legislation the intent of which is to provide for future contingencies, or to so remedy present practices as to avoid those contingencies. Now it happens that the conservation of water resources is not a matter that can be treated under ephemeral and emergency legislation Acts passed for this purpose must all be the result of legislative foresight. Their application to the needs of the country may be in the immediate present or generations hence. It is a far cry from such legislation to that enacted under the principles of the famous expression, " Posterity be damned." Summing up the whole matter of our present attitude, one can hardly avoid the reflection that we belong to the tribe of Esau, who for present gratification sold his birthright for a mess of pottage.

There is another reason why we have wasted our water resources. Being born of the tribe of Esau gives us wasteful tendencies, but these may be overcome, as have so many other barbaric habits. The reason why they have not been overcome is that the people as a whole have been so ignorant concerning the water resources. At the first settlement of this continent water resources were so abundant for the few people who came to these shores that there was no necessity for considering their extent. In this respect it is

extremely unfortunate that this continent was not first discovered on its western coast, for then the early settlers would have immediately been confronted with the necessity for considering the water resources. This abundance of water in the East continued to make it unnecessary to take a thought for the morrow through all the days of construction and reconstruction, and it is only within a recent period that this country has become so thickly settled that thoughtful men have deemed it wise to take an account of stock.

Probably 90 per cent. of our people know nothing of our water resources, and the remaining 10 per cent. know all too little. Here is emphasized the need of investigation. If we go back to first principles, it is clear that before we can write we must know the alphabet. Before the present day of steam propulsion came the elementary investigation of Watt and Stephenson; before the present day of electric transmission came the studies of Franklin, Gilbert, Faraday, Volta, and a host of others. The inference is obvious. Before our people can know the extent of their resources, and provide proper legislation for their development and protection, they must know our rivers, their flow, fluctuations, eccentricities, and every feature that contributes to or modifies their utilization as a natural resource. The engineering profession to-day is building great water works of various kinds and basing some of their most important calculations on empirical formulæ. They seek, for example, to determine flow, seasonal distribution, etc., by applying the data determined for one basin to supposedly similar conditions on another. There is much that is not well understood and much more that is understood by a few but has not been popularly disseminated. What, for example, does a water horse-power mean to the average man? It represents no tangible value, as does a barrel of oil or a ton of coal. Therefore, it is something easily and cheaply acquired by private interests. It is something too cheaply purchased and too profitably disbursed. Yet this average man, who knows nothing of the water resources, and to whom a million gallons of water or a thousand horse-power represent merely an indefinite figure, is the one *who shapes our legislative policies and who is responsible for the fact that we must look across an international border for our ideals in water conservation.*

I have said that the average man is responsible for the legislation, but the fact remains that we whose professions lead us into the consideration of water problems are responsible for the ignorance of that average man. We, and we alone, are the individuals who are in a position to teach concerning these matters and to provide for the proper investigations and encourage the proper legislation whereby a wise public policy may be adopted.

If we would sum up the water resources of the United States, we must begin at the sources of supply, namely, the individual drainage areas. Here are catchment basins receiving from the clouds the annual supply of rain. As the rain falls at various times and with varied intensity, so must these basins discharge the water. We have, then, a fluctuating condition, sometimes with rivers high and again with long seasons of low water. The ideal condition would be uniformity in discharge, but this can never be attained. We are not, however, prevented from approaching this ideal condition as closely as possible and, therefore, we are confronted, first of all, by the consideration of floods.

A flood is primarily a waste of water. Although we usually consider it solely as a damage to property, trade, and public comfort, its worst feature arises from the fact that it deprives us of water which might be put to useful purposes. Obviously, the way in which to arrive most nearly to the ideal condition of uniform discharge is to cut off the flood and to increase the low-water flow. Thus we may make both extremes come closer to the mean. To arrive at this end we must save the floods, place them in safe deposit where they can be drawn upon in times of water depression, just as the merchant draws upon his bank account, accumulated during prosperous business periods, at the time when he needs it in periods of financial depression. Our uplands are good for little, as a rule, except for growing of timber and the storage of water. Such uses do not interfere with the purposes of recreation which have become so important in American life, but rather enhance their value for such purposes. Therefore, it seems to the writer that the goal toward which all efforts should be directed should be that condition in which our rivers shall become effectively managed in their discharge. Thus would we not only save the water for beneficial uses, but we would effectively prevent a

large part of the losses due to our annual flood devastations, which amount easily to $100 000 000 per average year.

Having stored our floods, these waters can be released as needed for various purposes below. They can be used to supply cities, to irrigate fields, to assist in maintaining navigable depths in rivers, and, while descending to perform these services, these same waters can be made to turn power wheels for the benefit of manufacturing and commerce. The condition above described is ideal and many good men have regarded it as beyond realization. Doubt has been expressed in spite of the fact that in the few cases in which the idea has been put into practice great success has been realized. Nevertheless, the doubts of able men have prevented thorough investigation of the scheme on a large scale. It is not necessary to actually arrive at the ideal condition in order to receive benefit. There may be, by reason of engineering or natural difficulties, certain losses, certain failures to approach the condition just described, but until we have approached it as nearly as possible, we shall not have performed our work in the conservation of water, nor shall we have discharged our stewardship of this enormous resource.

Instead of conserving our flood waters, we have exercised the utmost ingenuity in increasing their violence. We have, for example, allowed the forests to be cut off and thereby increased the speed with which the precipitated water flows into the river channels. As this subject will be more thoroughly discussed in another paper at this convention, mere mention of the fact will suffice for present purposes. In our public lands we have granted water rights for a small tithe of their value, and in the majority of cases these grants have not resulted in productive development of the rights but merely tied them up, made them unavailable, and thereby assisted their speculative exploitation. By other and similar means and expedients we have established our reputation for improvidence. Unless our policies are reversed, American mankind will pay the price.

The impossibility of suitably covering a subject so great in scope as that implied in the title of this paper is already apparent. Realizing this in the beginning, the author has deemed it wise to avoid discussion of details concerning the extent and regional

distribution of water resources and to present a few thoughts with relation to general public policy. Summarily, it appears that the first step necessary in the conservation of our water resources is a distinct reversal of present public policies and conventional legislation. The second is to prosecute, with zeal, the scientific investigation of the water resources so that facts necessary to their intelligent treatment will be in hand. Third, it is necessary to disseminate broadly this information so that the average man who is responsible for our legislative policies will appreciate the necessity for reversal thereof. This is primarily the duty of engineers and water-works men. They alone possess the means of education. Finally, after the investigations have been concluded and we have at hand facts sufficient for our purposes, it will be necessary to treat the one great subject as a unit, with due regard for all the necessities imposed by the various interests of water utilization, to start our actual conservation work at the sources of supply, and there so to adjust the distribution of water that it may be made to serve in the most useful way all the needs imposed by demands of our present generation and the necessities and demands of those that shall come after.

FOREST CONSERVATION.

BY R. S. KELLOGG, ASSISTANT FORESTER, UNITED STATES FOREST SERVICE.

[Read September 23, 1908.]

Ours is primarily a wood-using civilization. Despite the introduction of substitutes for wood in the form of stone, cement, concrete, and steel, our consumption of timber has constantly increased from the earliest days up to the present time. Now our annual requirements exceed forty billion feet of timber, one hundred million cross-ties, four million cords of pulp wood, besides great quantities of other forms of forest products, such as firewood, posts, poles, mine timbers, etc. The per capita consumption of lumber in the United States was 215 board feet in 1850; now it is 470 board feet.

What has been the effect of this tremendous consumption upon our forests? One forest region after another has been attacked. With the exception of Maine, the New England states are cutting mostly second or third growth timber. The box factories there take white pine saplings down to six inches in diameter. The so-called "inexhaustible" white pine forests of Michigan are gone, and millions of acres of cut-over and burned-over land have gone upon the delinquent tax list. Michigan supplied 23 per cent. of the lumber production of the United States in 1880, and less than 5 per cent. of it in 1907. The value of the lumber production in Michigan since 1849 has been 50 per cent. greater than the output of gold in California, and it has all taken place without a thought for the future. The cream of our hardwoods is gone, and it is becoming more and more difficult to get in sufficient quantity the high grades of oak, yellow poplar, ash, and hickory that our great manufacturing industries require. The South's once great supply of yellow pine is rapidly giving way before axe and saw, fire and tornado. Half a generation more will, in most places, see little but remnants left of the Southern forests, and in that time the Pacific coast supplies will be heavily drawn upon.

The prices of forest products have risen more rapidly than those of other commodities. According to the reports of the Bureau of Labor, the quoted prices of the leading kinds of lumber on the New York market have risen twice as much in the last ten years as the average increase in all commodities. This indicates that the supply of timber is not keeping pace with the demand.

Since we cannot get along without timber, it follows that we must take the necessary measures to produce it. The present annual cut of forest products requires at least twenty billion feet of wood. To produce this quantity of wood without impairing the capital stock, our forest land must make an annual increment of 30 cubic feet per acre. Under present conditions of mismanagement and neglect it is safe to say that the average annual increment is less than ten cubic feet per acre for the entire area. This means that *each year's cut* at the present rate takes the growth of more than *three years.* The average age of the trees which are being felled for lumber this year is not less than one hundred and fifty years. The lumberman could not afford to replace them were he blessed with the prospect of unequaled longevity, since such long investments are unprofitable for private capital. In consequence there arises the necessity that the state and national governments, which do not need to look for so high a rate of interest as the private investor, and which are concerned with the promotion of the general welfare, should assume the responsibility of providing a future supply of timber.

The forest area of the United States is sufficient, if rightly managed, to produce eventually timber enough to supply every legitimate need. There is no reason why it should not some day be brought up to the point of yielding an annual increment of more than thirty cubic feet per acre, which will supply the quantity of timber now consumed, and which, if used economically, will be sufficient for a much-increased population.

By way of a concrete example of the necessity for forest preservation, let us note the main facts concerning the proposed Appalachian reserves. The Appalachian region, stretching from New England to northern Georgia, contains 75 million acres of rough or mountain land primarily adapted to the production of hardwood timber, and comprising portions of the watersheds of nearly all of

our great eastern and southern rivers. More than four-fifths of this area has been cut over, and some of it has been cleared, yet it is now furnishing half the annual quantity of hardwood lumber used in the United States. With management according to the principles of modern forestry, the annual growth of timber on this area could eventually be made equal to the quantity of hardwood now annually consumed in the United States.

Some of our greatest and most useful manufacturing industries as conducted at present are absolutely dependent upon a permanent supply of hardwood timber. Among these are cooperage, vehicle and furniture making, the combined annual output of which is valued at upward of four hundred million dollars. The hardwood supply essential for these industries and a multitude of other uses will soon fail unless vigorous action be taken by the national government and the heartiest coöperation be given by the states and individuals most vitally concerned.

Not less essential than for timber production is the proper handling of this great region for watershed protection, the regulation of stream flow to meet the demands of commerce, and the development of power for manufacturing. All the water gathered by the southern Appalachian and White mountains flows to the sea through navigable rivers. In the southern Appalachians there are no natural lakes to gather the flood waters. The only natural factor which tends to equalize the flow of the streams is the forest. In addition to the great property loss which always occurs as the direct result of a flood, there is a still greater though less appreciated loss in soil fertility. In 1896, Professor Shaler said:

"South of Pennsylvania there is, according to my reckoning, based on observations in every state in that upland country, an aggregate area of not less than three thousand square miles where the soil has been destroyed by the complete removal of the woods and the consequent passage of the earthy matter to the lowlands and to the sea. At the rate at which this process is now going on the loss in arable and forestable land may fairly be reckoned at not less than one hundred square miles per annum. In other words, we are each year losing to the uses of man, through unnecessary destruction, a productive capacity which may be estimated as sufficient to sustain a population of a thousand people."

Since that time the cutting of timber, fires and clearing have

greatly accelerated this rate of soil destruction. The property loss resulting from the floods along the Ohio River in January and March, 1907, amounted to nearly ten million dollars, most of which was sustained by the city of Pittsburg. The great loss of life and property which has just occurred in the Carolina floods is too recent to be accurately computed.

The government has already spent or planned to spend some fifty million dollars in an effort to improve the navigability of the streams which have their sources in the southern Appalachians. The total amount of water carried by these streams during the year is amply sufficient for navigation were the flow uniform. The attempt so far has been to *regulate* floods by means of dikes, retaining walls, dams, and locks, and to dredge out resulting bars and flats. This is not enough. It is time to adopt means of *prevention.* The most important of these are the maintenance of forests on the watersheds, and, in addition, the construction of necessary reservoirs to hold the excess run-off and distribute it throughout the year.

The Appalachian streams are of great and increasing importance as sources of power. A fair average of the rental value of the power which it is possible under present conditions to economically develop in the southern Appalachians is nearly forty million dollars a year. The capital invested in the manufacturing enterprises in New England which utilize the power of the streams that rise in the White Mountain region amounts to a quarter of a billion dollars. Water power has a use and value which is in proportion as it is steady and reliable. Such power cannot be obtained from a barren watershed.

The Appalachian region, therefore, is of extreme importance to the East because of its relationship to the hardwood timber supply, navigation, and power. That it must be properly protected cannot longer be questioned. The way to do this is by establishing state and national forests throughout the region, conducted in coöperation with the owners of private timberlands. The interstate relations make the problem primarily one for the general government to undertake. West Virginia cannot be expected to protect the watersheds of the tributaries of the Ohio because Pittsburg and Cincinnati suffer from floods. North

Carolina cannot justly be required to provide its sister states with timber and power. The silt coming from the mountains of eastern Kentucky may be finally deposited in the delta of the Mississippi, and that from western Virginia may choke up the Potomac and the James.

Every argument which is advanced to prove the necessity for protecting watersheds to regulate stream flow applies with redoubled force whenever the run-off from these watersheds is used for city and town supplies.

The national government, then, should acquire the backbone of the great Appalachian ridges, the right management of which is of most importance because of the interstate relations. Other states can establish state forests within their borders, as have New York and Pennsylvania, whose total is nearly two and a half million acres. The West has more than one hundred and sixty million acres of national forests. The East has none. This condition cannot last much longer. The establishment of forest reserves in the Appalachians has been recommended for years by the President, the Secretary of Agriculture, state officials, and a large number of scientific, technical, and trade organizations. The Senate passed the bill providing for these reserves last spring, as it has done before, and the indications are that the House will do so in the near future. When this is done it will mark the most decided advance in the conservation of our natural resources since the establishment of the first National Forest in 1891.

DISCUSSION.

THE PRESIDENT. The subject is now open for discussion,

MR. P. A. MAIGNEN. Is there any tariff on imported wood?

MR. KELLOGG. Yes, sir; there is a tariff of $2 per thousand feet on sawed lumber, but none on logs.

MR. MAIGNEN. In some European countries, where there are divisions of the forests, no more trees can be cut than are planted to take their place, and in some countries even a private owner cannot cut more from one portion of his land than he plants on some other portion. I was wondering if we could not have some such provision enforced in this country.

Mr. Kellogg. It might be possible, but I don't believe it is very probable. The people of the United States do not like restrictions very much, and what we will have to do, I think, aside from the national government acquiring such land as it can, is to use moral suasion rather than force, though there is a considerable sentiment in favor of the regulation of the cutting of timber on private lands. There is no question but what that sentiment is growing in the United States. The most radical step in that direction was taken in Maine last winter. I do not think the bill was passed by the Legislature of Maine, but the Legislature addressed an inquiry to the state Supreme Court, and the Court decided that it would be constitutional to prohibit the cutting of the smaller sizes of timber upon private land, where the cutting of that timber would seriously affect the public interest, having in mind, for one thing, the relation between forests and stream-flow.

Mr. R. S. Weston. I should like to ask Mr. Kellogg what the prevailing view among forestry experts is regarding the best method of reforesting burned-over areas? Is it considered better to let the wood follow along in natural sequence or to replant?

Mr. Kellogg. That depends to some extent upon the locality and the kind of timber. In general, if conditions are at all favorable, foresters are inclined to regard it as better to let Nature bring back the second growth of timber. It takes longer, but is much cheaper. Forest planting is an expensive operation. It will cost anywhere from five dollars an acre up to plant timber on a commercial scale where it has been destroyed either by fire or cutting. It does not cost you anything if conditions are favorable, except waiting a little longer, to let Nature seed over the area; and so, while there are considerable areas in the United States on which we shall have to reproduce our forests by planting, in general we hope to get our future growth of timber more from natural reproduction, simply because it is so much cheaper.

Mr. Allen Hazen. How old does white pine have to be before it will seed the adjoining area?

Mr. Kellogg. From about twenty years on. It seeds pretty early and grows rapidly. You will find in New England both natural and planted white pine, between thirty and forty years old, that is being cut and sent to the box factories now.

MR. HAZEN. There are sections of New England through which I drive every summer where the white pine has been exterminated because, generations ago, the farmers thought that it was a weed and that they would be better off if they could clear it all from their farms. On this land only birches and woods of less value now grow. I have sometimes thought that if a white pine could be planted here and there, not very near together, they would grow up and seed the whole country in the course of time, without very much expense.

MR. KELLOGG. They probably would.

MR. HAZEN. No one supports more cordially than I the proposition to establish national forest reserves and to have the government acquire the higher land on the mountain ranges that I am so fond of visiting and climbing over in the summer. I believe most thoroughly in propagating the forests and encouraging and extending them, because we shall need the lumber.

But there is one idea that has gone through this discussion of forest preservation about which I am not satisfied, and that seems to be open to reasonable doubt. I refer to the effect of forests in maintaining the flows of our streams for useful purposes. It has been often assumed that the flow of water from a forested area is larger and more constant and more dependable than from a like area of land that is not forested. I have looked in many places, and through a long period of time, for certain, definite evidence upon this point, but I have found nothing satisfactory. If there is really anything of importance in this idea it would seem that it ought to be possible to secure evidence of it of a nature that could not be questioned.

I am somewhat familiar with the Connecticut valley. I remember the hills that I used to climb years ago, as a boy, from which I could see unbroken forest in all directions. Those areas have now been completely cleared of lumber. They are growing up again, to be sure, as fast as they can, but it is certain that the amount of forest on the catchment area of the Connecticut is much less than it was twenty-five years ago. The flows of the Connecticut River have been recorded by gagings extending over many years. From these records, which I have seen, it appears that the flows (and I refer especially to the summer or dry weather flows) have been

greater in recent years since great inroads have been made in the forest areas than they were twenty-five or thirty years ago, when there was certainly much more forest.

If the inquiry is extended to the Merrimac, the Sudbury, the Croton, and other catchment areas for which accurate gagings are available, so far as I know the same results will be found.

I do not think the flows of recent years have been greater because the forests have been cut off, but there is certainly a great lack of evidence that the cutting off of the forests has reduced the flow.

I was greatly interested in Australia last year in finding that some of the engineers and water-works people had exactly the reverse idea from the one which seems to be current here. The catchment areas which serve to supply some Australian cities are covered with forest of a density which can hardly be imagined by one who is only familiar with forests in cool climates; and the idea is held very firmly and by many people that these forests take the water which falls upon them and upon the ground and evaporate it and dissipate it and prevent it from flowing off to the reservoirs that supply the cities; and thousands of acres of those forests upon catchment areas have been ring barked to kill the trees, with the idea of preventing the dissipation of the water by them, and in this way of securing a larger amount to supply the cities.

I inquired for data that would justify this practice, and it is only fair to say that I was as little satisfied as to its being well founded as I am in doubt as to whether the opposite view is well founded in our climate.

I should like to ask Mr. Kellogg how far he has studied this matter, and if he has any figures of any description that are reliable and certain which indicate, or which even tend to indicate, that the run-off from forested areas is greater or more certain than from like areas that are not forested.

Mr. Kellogg. There are a great many things that complicate the matter, as Mr. Hazen has evidently found out on going into it a little. The only way to ever answer the question on a scientific basis is to have a long series of various kinds of records, — records of the actual condition of the watershed so far as its cover is concerned: whether it is timbered or cut over or burned over or grassed; an accurate knowledge of what the geological formation

is; what the shape of the drainage basin is; an accurate record of the precipitation through a series of years, and an accurate record of the run-off or gagings of the streams. It seems to me we must have all this evidence in order to answer the question, because all these factors influence the run-off, and we do not have such complete knowledge, so far as I know, upon any drainage basin in the United States. If I am wrong, I hope Mr. Hazen or Mr. Parker will correct me. Because we do not know these things at present, we have to draw our conclusions from what meager data we do have, and also somewhat from theoretical considerations. It does look from some data as though there were a close connection, while other data do not seem to show anything either way, — I will say that frankly. The figures I read here a little while ago indicate pretty strongly that there has been an increase in the run-off of certain of our important rivers, and we know that during the period covered by the record the only change which has taken place on the watershed has been the cutting off of a considerable quantity of timber. The records which I read here, which extend in some cases over a period as long as seventy years, show an increase in the number and duration of floods in such rivers as the Ohio and the Cumberland.

The theoretical considerations are something like this. We know that where we have a forest for a long time upon an area which is not damaged by fire, we get a gradual accumulation from decaying trees, leaves, and undergrowth which makes a blanket over the surface of the ground, and that blanket is somewhat in the nature of a sponge. It would certainly seem that when water falls upon such a blanket it would be retarded in its flow and more would sink into the ground than if we had a barren watershed covered only with rock, or possibly with gravel or very hard soil,

I do not think it is at all common to claim that the total run-off from a watershed is likely to be increased by having a forest upon it. The total run-off in a series of years may be just as great from a forested watershed as from a barren watershed, but it would seem that the run-off would be regulated, that the floods might be strung out further and not reach as high a stage, and that the low-water stage might not be so low in the case of a protected watershed as in the case of a non-protected watershed.

This matter which Mr. Hazen brought up in connection with Australian watersheds, that is, the loss of water by its being taken up and transpired into the atmosphere by the forest, probably has quite a little in it; but, on the other hand, such observations as have been made, particularly in Germany, indicate that there is no more moisture transpired by forests than there is by a covering of grass or some other kind of vegetation. But it certainly does seem reasonable that a forest must have a good deal of restraining influence upon the run-off, and it is unquestionable that the run-off from a well-protected watershed does not carry nearly as much silt as it carries from an unprotected watershed. We have case after case of the most striking kind, particularly through the South, where, when the timber has been removed, erosion of the face of the country has immediately set in, and set in where it did not exist before; and that means that your water is polluted to a certain extent, and it most certainly means that your water course is filling up with silt.

MR. FRANK L. FULLER. Mr. President, this matter which Mr. Hazen has spoken of I think is very important, and I have often thought of it myself, because we all know how the roots of trees will run down into the soil in search of moisture. We have seen the roots of elm-trees running into sewer pipes and into all sorts of moist places, apparently seeking to get to water. I noticed some time ago, in a covered reservoir, where some cracks had been made by a settlement in the bank, causing a slight aperture through the concrete, which was covered with earth, grass roots had gone down three or four feet, I should think, to get at the moisture underneath. It was rather surprising to me that those roots should have extended down so far.

It seems to me that some experiments should be made, and I wonder that they have not been made, as to how much moisture a tree will take up. It would seem as though a tree might be planted in some sort of an inclosed watertight basin, supplied with water, and in some way the amount of moisture taken up by the tree and evaporated gotten at. Of course any amount of water which is evaporated into the air is so much lost to the soil, and, therefore, lost to the drainage area. It may fall again on the same drainage area in the form of rain, but it may not.

There is one other thought which occurs to me, and that is in connection with the retention of snow in the forests. Mr. Kellogg did not mention that matter, but he can probably give us some information in regard to it. Oftentimes we go into the woods in New England as late, perhaps, as the latter part of May, and find considerable snow retained in the shady portions of the forest. That snow, of course, will gradually get into the streams, and will cause much less variation in the flow of the stream than it would have caused if it had all gone off suddenly, as it would have done if the area had been unwooded. It seems to me there is one point where the advantage of a wooded area is considerable.

MR. KELLOGG. That is what ordinarily occurs, but let me give an instance on the other side which will bear out the point Mr. Hazen made that there is a great diversity of opinion on these subjects. A man told me not long ago that in his opinion the forests in the southern Appalachian hills are really responsible for the floods. His idea was that the snow collected in the forest during the winter and then melted and went out all at once in the spring, and that made the floods.

MR. FULLER. I suppose that in case of a warm rain the snow would go out fast, and perhaps some of our heaviest floods are caused in that way, — by the combined effect of the melting snow and the rain, — but it would seem as though the snow being retained and held back by the forest was an advantage.

MR. KELLOGG. In general it would seem as though that were so, but I cannot say offhand what the European observations have been, so far as the effect of the retention of snow upon the subsequent run-off is concerned. The European observations, as I recollect, show, as I said a minute ago, that the amount of water transpired by forest is at least no greater, and in some cases less, than by other forms of vegetation. You get transpiration everywhere where there is vegetation, because water performs its function in plant life principally as it is transpired. It acts there somewhat as in the development of water power. It is only as water passes from one condition to another that its use is developed.

MR. HAZEN. Mr. Kellogg has described the humus blanket, so-called, and its supposed effect in maintaining flow. I think that

his principle is right, but it is my idea, after giving the matter considerable attention, that the real blanket which holds the winter water and gives it up in summer is the layer of glacial drift that is found on nearly all of our northern streams, and also the older deposits with similar physical properties which occur along the Atlantic coast to the southward, and other similar pervious deposits in other parts of the country. I know that this material is often many feet in depth and is pervious and has a great capacity for taking up water and holding it and giving it out slowly, and we know, from the records of rainfall and of run-off, that this material, or some material, holds back the rainfall in the months of excess and gives it out in the months of deficiency, and it seems to me that this pervious, gravelly material has so much greater capacity in this respect than any possible humus layer could have that the influence of the humus, if any, must be trifling in amount in comparison with that of the sand and gravel blanket.

Mr. W. C. Hawley. It may be of interest to call attention to the fact that the flood in the Allegheny River last year was the most serious flood they ever had, and as the result of the drought which western Pennsylvania has been experiencing for some two or three months, the streams in that locality are to-day lower than they have been for a period of perhaps forty or fifty years. I haven't any exact data on that, but statements have been published in the newspapers within the last week or ten days to that effect. Of course the forests on the Allegheny River have been to a considerable extent removed. The banks have been encroaching more or less upon the stream in the vicinity of Pittsburg, also, from year to year, as they have been built upon, and this may account in part for the flood last year reaching so unusual a height.

Mr. Albert Blauvelt. I should like to ask the reader of the paper whether any of the data concerning water flow have been made out on the idea that the question is one of relation of the forest to the character of the earth's surface. I don't know that I make myself clear. We know perfectly well that a tree itself takes up a great deal of water and evaporates it into the atmosphere. That water never reaches the ground at all. It also holds a great deal of snow in the winter time, which melts on the tree in warm days and returns to the atmosphere, wholly irrespective of the

breathing action of the tree or moisture drawn from the ground. We know very well if we had a surface made of sheet tin, with convenient flow points, like the roof of a house, and had sponges on it instead of forest, we would retain considerable water, but otherwise we would immediately have a rapid run-off. Now I am asking for information whether the studies have gone into a consideration of the thought that the real point may be, not whether forest is present or absent, not whether the soil is water-tight on the surface or is capable of retaining great quantities of moisture, as the last speaker mentioned, but whether it is not a question of what are the relations between those two. In other words, if you have a surface soil capable of quick drainage and incapable of retaining water, then you must have forests. And cannot some of these discrepancies be explained on the ground that where there is a lack of water you have a surface which has failed to retain the water? In other words, that you can have a well-regulated flow either with plenty of forest or a good absorbent surface to the earth, but you must have one or the other, and you will get into trouble if you fail as to both.

MR. KELLOGG. I think that is a point well stated. The records which have been taken up to the present time I do not believe have been from that standpoint, and that is particularly true of the earlier records, because we began this work in rather a haphazard fashion, without taking all the factors into consideration. When the first records on some of these streams were taken seventy years ago nobody thought of forestry. That didn't get started in the United States until sixteen or seventeen years ago, and it has only been since that time we have been considering some of these questions. We are just now getting at the heart of them. Heretofore we have had only partial records, in some cases of the rainfall and in some cases of the condition of the watershed, and when we try to tie them up we find that they were not taken with the object in view of correlating these different things, because we hadn't got that far into the subject.

MR. BLAUVELT. Personally, I believe that we must have a sponge either in the forest or on the ground.

MR. KELLOGG. I should think so, and that suggests a question I wanted to ask in regard to the New England streams. Does any-

body here remember how far south the line of glacial drift extends? My remembrance is that it is not south of New York.

A Member. It goes to New Brunswick, N. J.

Mr. Hazen. And there are tertiary deposits beyond that, which have the same characteristics, extending down through New Jersey.

Mr. M. N. Baker. It is quite evident from the discussion we have had this afternoon that there is much need of giving careful attention to the subjects which have been before us. The question of the transpiration of forest growths is discussed in Fernow's " Economics of Forestry." (1902.) Some years ago, Mr. C. C. Vermeule and the late George W. Rafter, and others, discussed forests and run-off before the American Forestry Association. The latest contribution to the subject has just been made public in an advance copy of a paper by Lieut.-Col. H. M. Chittenden. (Proceedings of the American Society of Civil Engineers, for September, 1908.)

I think the consensus of opinion here agrees quite well with the consensus of opinion generally, as far as one can gather it, and that is that forests have comparatively slight influence upon rainfall, but more influence, however, upon the run-off, and that their influence upon the run-off is more in equalizing the flow, particularly floods. The forest floor, or blanket, or sponge, as it has been called, has a very great influence upon violent fluctuations of stream flow.

The effect of forests upon the distribution of the run-off as related to the snowfall is also very material. Some years ago Prof. L. G. Carpenter, of Fort Collins, Colo., brought out a very interesting bulletin dealing with this matter of snowfall retention in forested area. On June 24 of this year, in company with the American Society of Civil Engineers, I was up at about an elevation of 11 660 feet, on one of the railways which is being built from Denver through to Salt Lake City. As we got up toward that altitude we saw very unmistakable evidences of the effect of forest upon the snow. In the heavily wooded areas along the railroad track there were snow banks many feet in thickness, whereas out where the sun would strike, and where there was a southern exposure, there was practically no snow at all.

Mr. H. N. Parker. Mr. President, it seems to me that this discussion gives point to a portion of Mr. Leighton's paper, in which he said it was necessary for us to take up these problems as a whole. In the past a lack of proper legislation and possible lack of breadth of view on the part of investigators has led us to consider each question by itself, so while we have had gaging stations, for instance, established on the rivers, it may be that they have not been established at places where at the same time observations could be made of the effect of cutting off the forest and the work which the forestry bureau was doing. It seems to me we have got to proceed in a businesslike as well as scientific sort of way in the investigation of all these matters connected with the conservation of our natural resources, and, as Mr. Leighton said, educate the ordinary citizen up to the point where he will insist on his state legislature, his municipal government, and the national government appropriating funds to carry on this work through a sufficient length of time to get definite results.

Prof. Edward W. Bemis. Mr. President, I think this discussion has been very valuable. It may be worth while to bear in mind that whatever doubt we may have as to the effect of forests upon the fall of water, there is no doubt, as Mr Hazen has expressed it, as to the importance of the forest policy of the government in relation to the timber supply, and there seems to be some degree of warrant for the opinion that it has a probable effect upon climate and upon the rainfall; so that while we are still having some doubts as to the full effect of the forests upon the water supply, we are sure enough of our other points to uphold the policy of the government for a large development of government forests and a thorough investigation by the government of the forestry question.

I believe Europe must have exact data, such as have been called for to-day and not produced, upon the flow of water in rivers. I can hardly imagine that the French and German governments could have carried on their works as many years as they have without getting very definite data, which no one here seems to be able to quote, on that one point of the flow of water. But, as I say, that is one point only, and we may still have our doubts on that and have no doubt whatever on the general policy of the government on the subject.

It has seemed to me for a long time that the decades to come will look upon the present administration as having performed its absolutely greatest service, of all the many services it has performed, in its conservation of our natural resources. That, it seems to me, we can have very little doubt upon. It has been the great stock argument, as you are doubtless aware, of many of the economists, that the forestry question is the absolute proof of the mistake of the individuals, and of the philosophy of Herbert Spencer and others, in their theory that the interests of the individual and the interests of society are identical. The forestry question has been often cited as the absolute proof of the falsity of that opinion, because the individual's interests do not run generally over twenty or thirty years, while it takes from forty to one hundred years to develop the economic value of the forests, and, therefore, only society in its organized capacity is able to look upon the question broadly. The individual cannot look on it broadly because the individual wants to reap in his own lifetime. And in so far as it is not purely a question of lumber or timber which may be grown in the lifetime of the individual owner, and so far as there is any effect on climate, or on the rainfall, and broadly on the country, that, of course, is altogether a benefit to society at large, and, therefore, only society at large can take an interest in the subject.

I think there is enough evidence already at hand to warrant the idea that, independent of any party affiliations, we cannot too strongly approve large acquisitions of government forests. One of the beauties of this moment is that it is independent of all partisan spirit. The movement is becoming a general one, but does not seem yet to overcome the opposition of certain selfish interests in the House of Representatives. I think, however, in the country at large, the sentiment is getting to be almost overwhelming, and it is for us to make it more so if possible. I have enjoyed this discussion very much indeed, and I hope that we may be able, or Mr. Kellogg may be able, to turn to the French and German data, for I am sure that there must be such, on the point which has been especially discussed to-day.

A MEMBER. When I was a small boy there used to be a great deal said about the cutting off of the forests, that it was going to

decrease the rainfall; I don't hear anything said about that subject nowadays. I have had occasion to work somewhat on a small scale and argue from the smaller to the greater. It would seem as if it were reasonable, perhaps, that if we cut off the forest we thereby open up more and more freely the channel ways for the water, and that, therefore, the water would get quicker to its main outlet and would seem to be increased in quantity, there would be greater floods, and we would get the impression that there was a greater total amount; while with the trees in large areas there is less free access to the water channels and, therefore, a greater regulation of the flow.

I should like to know whether there has been in the forestry examinations anything on the first point, that is, a decreased actual total rainfall. I have noticed this on small tracts. We have had occasion to look up many cases of claims for damages due to development of localities. People have come in and been almost black in the face over the damage done by floods. They have said, "All my ancestors, and the people from whom I bought the property, never knew such floods; we have more water coming down to-day than ever came before." That is what I have heard day after day. Now, what is the fact? The fact is, that the rainfall statistics show the same averages, fluctuating up and down, up and down, up and down, but practically the same that they were fifty years ago; but the development of the region, the building of streets, the draining of swamps, the removal of small tracts of forest, allows the water to flow more quickly. I imagine that that is going to be one of the serious points in connection with our forestry conservation. If we can control the water by dams and reservoirs of various sizes, by improved lands and some forest, we will get the same result from the point of view of the conservation of the water that we would from actual forest lands.

Mr. Parker. We all know the effect of a wagon track through a forest region, and have seen on the mountain side how the water will seek such a track and flow down rapidly through that free channel way. There are very many things which complicate this problem which we are now discussing.

Mr. George A. King. I should like to ask Mr. Kellogg if he has any figures as to the waste of lumber and wood in forest fires, and

if that is not one of the most serious problems in the protection of the forests.

Mr. Kellogg. It is unquestionably one of the most serious problems we have, and it is more serious from the standpoint of private forestry than any other thing. We haven't any reliable data upon the annual loss from forest fires in the United States. It has been estimated at from $25 000 000 to $100 000 000. We intend within the next month or two to begin the collection of statistics on the damage by forest fires in the United States in 1908. The fires this year throughout the United States have been worse than they have any year since the noted fires in Minnesota in 1894, and we are going to get all the information possible in regard to them.

There is absolutely no question that fire is one of the most serious hindrances to the practice of forestry by individuals and by large companies and corporations in the United States, but there is also absolutely no question that fire can, in the main, be prevented. It is being done almost completely in the national forests. We haven't entirely eliminated fires, but we have almost, so that the amount of timber which is destroyed by fire each year in the national forests is almost negligible as compared with the amount of timber in those forests. On the other hand, it was true, up to the time of the establishment of the national forests in the Rocky Mountain region, that enormous quantities of timber were destroyed by fire. Fires are preventable, but with the exception of what has been done by the national government and by two or three states, they have not been prevented.

Mr. Morris Knowles. I had occasion some time ago to look up some foreign records. In a translation by one of the army officers (Gen. Godfrey Weitzel, of the United States Engineer Corps) of a paper by Gustav Wex, reference is made to observations upon some of the streams of Germany and Austria, running back some one hundred to one hundred and fifty years. While the data were not entirely complete, conclusions were drawn as to the relation of forests to run-off. It appears that floods had increased for those areas where the forests had been cut away, but no mention was made in regard to rainfall or its distribution, or of many other conditions; simply the fact was given that the forests had

been cut off and that certain stream flows showed that for recent periods there were notably higher floods and lower summer flows than before.

I believe the distribution of the rainfall is one of the most important items, and upon this we have had but little data until recent years.

The late flood in the Ohio Valley, which was one of the largest ever recorded, was from a rainfall upon a limited area, mostly upon one tributary, namely, the Monongahela. It backed up into the Allegheny somewhat, and produced in the Ohio River a marked flood. The distribution of the rainfall as to the season and as to the different portions of the watershed, and as to the state of the soil and vegetation, must have a great effect upon the surface run-off.

Until facts can be secured along this line, where there are so many different opinions, no definite conclusions can be reached. We need more information, our discussions are based upon insufficient data, and I hope that this consideration of the subject will cause us all to use our influence with those who vote and appropriate the public moneys for the uses of such departments of our government, to see that there shall be liberal allowances to conduct such investigations. We may not realize the benefit in our day; as Professor Bemis has well said, it is a work for society as a whole, because of its long-continued effect; but by securing the data we shall have done something for the benefit of those who come after us.

Mr. A. A. Reimer. Our city of East Orange, N. J., has gone into this matter within the last year and started on our watershed the development of a nursery and plantation. We have about eight hundred acres, and of this, possibly 30 per cent. is a sort of rough forest. We have not gone at this question with the view of conserving the water supply primarily, for it will probably have no direct effect upon that at present, as our supply is entirely from artesian wells, but we have gone at it from the standpoint of lumber values, not figuring for to-day, of course, but for the future. We are making a very thorough study of the question. The state has lent us its expert, Mr. Alfred Gaskill, who is our general adviser, and we are following out his plans to the letter, and hope that in the course of ten years we will have as hand-

some a stand of fine lumber as can be found in our region. We have it in mind that this will be an object lesson, and we hope eventually that others around us will see the good result, and thereby we may receive a benefit to our water supply, as we realize that if there is anything in the idea of the retention of the rainfall by forests, artesian supplies will receive the same benefit that surface supplies will, and if forest areas can be developed within from three to ten miles of us on land which to-day is absolutely worthless for anything but forest, we believe we will receive in that way a benefit to our water supply. So we are not entirely unselfish, either from the standpoint of water supply or lumber, but at present the main point is the lumber supply, and we are developing a tract of land that in the next thirty to fifty years will furnish the finest kind of lumber.

MR. M. N. BAKER. It ought to be noted, I think, in connection with this discussion, that for some years past a number of municipalities and a few private water companies have been going quite extensively into the same line of work that has been mentioned by the last speaker. Four or five years ago I gathered quite a lot of information regarding forestry works on water-works drainage areas. I should suppose that since that day there must have been many municipalities, and perhaps a few more companies, who have joined ranks of those who at that time had taken up the work. As I remember it, there were half a dozen or some such number of rather notable instances of forestal work on drainage areas of American water supplies. In England considerable work of this kind has been done, and some very interesting reports have been made on forestry operations by the Liverpool works.

STREAM FLOW DATA.

BY CHARLES E. CHANDLER, CIVIL ENGINEER, NORWICH, CONN.

[Read September 24, 1908.]

At the November, 1907, meeting in Boston, I presented some tables of stream flows which were, with the accompanying explanations, printed in the December, 1907, JOURNAL.

Later I had tables prepared showing the flow of other streams,

TABLE No. 10.*

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile, arranged chronologically.

Year.	Jan.	Feb.	Mch.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1875	0.159	2.315	2.482	4.718	1.838	1.346	0.497	0.612	0.321	1.000	2.015	0.903
1876	0.995	2.116	6.862	5.094	1.761	0.343	0.283	0.627	0.285	0.361	1.683	0.702
1877	1.019	1.469	7.448	3.703	2.153	0.924	0.312	0.187	0.092	0.977	2.193	1.995
1878	2.800	3.814	5.426	2.516	2.158	0.782	0.199	0.736	0.249	0.799	2.619	4.916
1879	1 083	2.647	3.605	4.821	1.723	0.640	0.243	0.611	0.218	0.109	0.318	0.716
1880	1.733	2.765	2.126	1.808	0.796	0.271	0.273	0.184	0.124	0.157	0.318	0.271
1881	0.642	2.392	6.195	2.392	1.493	2.070	0.428	0.229	0.305	0.287	0.611	1.199
1882	1.920	3.718	4.392	1.342	1.998	0.818	0.133	0.086	0.474	0.463	0.324	0.487
1883	0.518	1.598	2.492	2.088	1.450	0.464	0.178	0.122	0.141	0.288	0.317	0.299
1884	1.540	4.397	5.857	4.415	1.594	0.644	0.346	0.397	0.068	0.129	0.271	1.431
1885	1.910	2.095	2.433	2.808	2.067	0.659	0.096	0.372	0.187	0.519	1.822	1.816
1886	2.260	7.428	3.185	3.013	1.114	0.314	0.179	0.146	0.182	0.225	1.041	1.578
1887	4.006	4.377	4.437	4.053	1.561	0.640	0.178	0.331	0.172	0.294	0.570	0.995
1888	1.629	3.011	5.009	4.093	2.526	0.652	0.182	0.587	1.786	3.093	4.267	4.708
1889	4.305	1.850	2.071	2.182	1.361	1.011	0.980	2.216	1.274	1.903	3 003	3.467
1890	1.941	2.366	5.636	2.900	2.114	0.878	0.166	0.204	0.708	3.515	1.879	1.541
1891	4.669	5.393	6.889	3.708	0.902	0.639	0.231	0.252	0.314	0.325	0.472	0.842
1892	2.893	1.459	3.024	1.347	1.948	0.662	0.331	0.433	0.354	0.195	1.088	0.750
1893	0.671	2.386	5.020	3.287	4.460	0.681	0.244	0.280	0.167	0.343	0.494	1.242
1894	1.082	1.533	3.462	2.537	1.299	0.648	0.249	0.323	0.232	0.579	1.293	1.108
1895	1.600	0.837	3.728	3.901	0.984	0.270	0.357	0.354	0.138	2.133	4.296	2 767
1896	1.677	4.140	5.937	2.311	0.557	0.617	0.147	0.088	0.600	0.916	1.019	1.016
1897	1.307	1.651	3.968	2.290	1.416	1.488	1.018	0.914	0.282	0.145	1.406	2.450
1898	2.534	4.675	4.028	2.829	1.928	0.820	0.357	1.713	0.571	1.795	3.072	2 783
Av.	1.871	2.935	4.405	3.090	1.717	0.762	0.317	0.500	0.385	0.856	1.516	1.616

* Note that numbers of tables are consecutive with those in the previous paper (JOURNAL, December, 1907, p. 464).

and both sets with explanations were printed in the 1908 Proceedings of the Connecticut Engineers' Association. I suggested to Mr. Kent that these additional tables might be printed in some number of the JOURNAL if it were thought best, and he desired that I present them here.

Three of the additional tables presented contain Sudbury data. The tables presented to the Connecticut Association included the thirty-two years, 1875 to 1906. The months showing minus flows were something of a stumbling block. Mr. FitzGerald has written me that the passing of so much Nashua River water through the Sudbury watershed during the years since 1898 makes the deduced

TABLE No. 11.

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile arranged in order of magnitude for each year.

Year.	1	2	3	4	5	6	7	8	9	10	11	12
1875	0.159	0.321	0.497	0.612	0.903	1.000	1.346	1.838	2.015	2.315	2.482	4.718
1876	0.283	0.285	0.343	0.361	0.627	0.702	0.995	1.683	1.761	2.116	5.094	6.862
1877	0.092	0.187	0.312	0.924	0.977	1.019	1.469	1.995	2.153	2.193	3.703	7.448
1878	0.199	0.249	0.736	0.782	0.799	2.158	2.516	2.619	2.800	3.814	4.916	5.426
1879	0.109	0.218	0.243	0.318	0.611	0.640	0.716	1.083	1.723	2.647	3.605	4.821
1880	0.124	0.157	0.184	0.271	0.271	0.273	0.318	0.796	1.733	1.808	2.126	2.765
1881	0.229	0.287	0.305	0.428	0.611	0.642	1.199	1.493	2.070	2.392	2.392	6.195
1882	0.086	0.133	0.324	0.463	0.474	0.487	0.818	1.342	1.920	1.998	3.718	4.392
1883	0.122	0.141	0.178	0.288	0.299	0.317	0.464	0.518	1.450	1.598	2.088	2.492
1884	0.068	0.129	0.271	0.346	0.397	0.644	1.431	1.540	1.594	4.397	4.415	5.857
1885	0.096	0.187	0.372	0.519	0.659	1.816	1.822	1.910	2.067	2.095	2.433	2.808
1886	0.146	0.179	0.182	0.225	0.314	1.041	1.114	1.578	2.260	3.013	3.185	7.428
1887	0.172	0.178	0.294	0.331	0.570	0.640	0.995	1.561	4.006	4.053	4.377	4.437
1888	0.182	0.587	0.652	1.629	1.786	2.526	3.011	3.093	4.093	4.267	4.708	5.009
1889	0.980	1.011	1.274	1.361	1.850	1.903	2.071	2.182	2.216	3 003	3.467	4.305
1890	0.166	0.204	0.708	0.878	1.541	1.879	1.941	2.114	2.366	2.900	3.515	5.636
1891	0.231	0.252	0.314	0.325	0.472	0.639	0.842	0.902	3.708	4.669	5.393	6.889
1892	0.195	0.331	0.354	0.433	0.662	0.750	1.088	1.347	1.459	1.948	2.893	3.024
1893	0.167	0.244	0.280	0.343	0.494	0.671	0.681	1.242	2.386	3.287	4.460	5.020
1894	0.232	0.249	0.323	0.579	0.648	1.082	1.108	1.293	1.299	1.533	2.537	3 462
1895	0.138	0.270	0.354	0.357	0.837	0.984	1.600	2.133	2.767	3.728	3.901	4.296
1896	0.088	0.147	0.557	0.600	0.617	0.916	1.016	1.019	1.677	2.311	4.140	5.937
1897	0.145	0.282	0.914	1.018	1.307	1.406	1.416	1.488	1.651	2.290	2.450	3.968
1898	0.357	0.571	0.820	1.713	1.795	1.928	2.534	2.783	2.829	3.072	4.028	4.675
Av.	0.198	0.283	0.450	0.629	0.813	1.086	1.355	1.648	2.250	2.810	3.584	4.911

flow less precise than in previous years. The years since 1898 contain all the minus months. On this account the Sudbury tables presented to-day include only the twenty-four years, 1875 to 1898, and probably the flow of these years is more useful than the flow of the thirty-two years. This makes the tables of permanent value without further modification.

The present tables include the Nashua flows for ten years, 1897 to 1906, arranged chronologically, in order of magnitude yearly, and in order of magnitude for full term. This table will be modified by the addition of future data.

The Merrimac data for seventeen years, 1890 to 1906, measured weekly, are given in order of magnitude. This table will be modified by both future and previous records when they are available.

This table is accompanied by one giving the number of weeks in the average of these years that any given flow has occurred and at any development the percentage available. It seems to me that these Merrimac tables, prepared from data furnished by Mr. Hale, are well worth the labor they cost.

I hope that next year Mr. Hale will give us the Merrimac data chronologically and in order of magnitude for each year, and for the full term from a much earlier date than 1890 up to 1908, and that other engineers having such data regarding other streams will give us all the benefit of them, at least chronologically.

Now I wish the limitations of this and preceding papers to be distinctly understood. There is no attempt to make a rule for determining the available flow of every or any particular stream under all circumstances. The aims and objects are:

1. To put in print for the use of all members, data heretofore not in print, or available to but few members.

2. To put these data in form of second-feet per square mile instead of second-feet for the particular place where the measurements were made.

3. To arrange these data not only chronologically, which in many cases is the most useful form, but also in order of magnitude for each year.

4. To also arrange the data in order of magnitude for full term, which is an unusual, but more precise, method of eliminating all unavailable storm flows in water-power developments.

5. The available percentage of the flow for any development is added in some cases.

These are basic tables. They can be used without modification for twenty-four hour per day use. For ten or eleven hours the results at different seasons of the year must be modified according to the opportunities on the stream for night storage and other local conditions.

The papers by Messrs. Main, Herschel, and Hale, printed in the September, 1907, JOURNAL, leave little to be desired in the way of methods for the application of stream flow data to especial cases.

TABLE No. 12.

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile arranged in order of magnitude of whole term, 1875 to 1898 inclusive.

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.068	0.182	0.283	0.357	0.612	0.837	1.114	1.594	1.948	2.392	3.072	4.392
2	0.086	0.184	0.285	0.357	0.617	0.842	1.199	1.598	1.995	2.392	3.093	4.397
3	0.088	0.187	0.287	0.361	0.627	0.878	1.242	1.600	1.998	2.433	3.185	4.415
4	0.092	0.187	0.288	0.372	0.639	0.902	1.274	1.629	2.015	2.450	3.287	4.437
5	0.096	0.195	0.294	0.397	0.640	0.903	1.293	1.651	2.067	2.482	3.462	4.460
6	0.109	0.199	0.299	0.428	0.640	0.914	1.299	1.677	2.070	2.492	3.467	4.669
7	0.122	0.204	0.305	0.433	0.642	0.916	1.307	1.683	2.071	2.516	3.515	4.675
8	0.124	0.218	0.312	0.463	0.644	0.924	1.342	1.713	2.088	2.526	3.605	4.708
9	0.129	0.225	0.314	0.464	0.648	0.977	1.346	1.723	2.095	2.534	3.703	4.718
10	0.133	0.229	0.314	0.472	0.652	0.980	1.347	1.733	2.114	2.537	3.708	4.821
11	0.138	0.231	0.317	0.474	0.659	0.984	1.361	1.761	2.116	2.619	3.718	4.916
12	0.141	0.232	0.318	0.487	0.662	0.995	1.406	1.786	2.126	2.647	3.728	5.009
13	0.145	0.243	0.318	0.494	0.671	0.995	1.416	1.795	2.133	2.765	3.814	5.020
14	0.146	0.244	0.321	0.497	0.681	1.000	1.431	1.808	2.153	2.767	3.901	5.094
15	0.147	0.249	0.323	0.518	0.702	1.011	1.450	1.816	2.158	2.783	3.968	5.393
16	0.157	0.249	0.324	0.519	0.708	1.016	1.459	1.822	2.182	2.800	4.006	5.426
17	0.159	0.252	0.325	0.557	0.716	1.018	1.469	1.838	2.193	2.808	4.028	5.636
18	0.166	0.270	0.331	0.570	0.736	1.019	1.488	1.850	2.216	2.829	4.053	5.857
19	0.167	0.271	0.331	0.571	0.750	1.019	1.493	1.879	2.260	2.893	4.093	5.937
20	0.172	0.271	0.343	0.579	0.782	1.041	1.533	1.903	2.290	2.900	4.140	6.195
21	0.178	0.271	0.343	0.587	0.796	1.082	1.540	1.910	2.311	3.003	4.267	6.862
22	0.178	0.273	0.346	0.600	0.799	1.083	1.541	1.920	2.315	3.011	4.296	6.889
23	0.179	0.280	0.354	0.611	0.818	1.088	1.561	1.928	2.366	3.013	4.305	7.428
24	0.182	0.282	0.354	0.611	0.820	1.108	1.578	1.941	2.386	3.024	4.377	7.448
Av.	0.138	0.235	0.318	0.491	0.694	0.981	1.395	1.773	2.149	2.692	3.783	5.367

TABLE No. 13.

South Branch Nashua River at Clinton. 119 Square Miles.

Monthly flows in second-feet per square mile, arranged chronologically.

	Jan.	Feb.	Mch.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897	1.232	1.440	4.270	2.525	1.800	1.828	2.231	1.386	0.528	0.377	1.984	3.521
1898	2.418	2.530	4.778	3.137	2.151	1.281	0.514	2.049	1.045	2.334	3.358	3.189
1899	3.236	1.687	4.295	5.224	1.344	0.869	0.548	0.365	0.387	0.379	0.665	0.555
1900	1.232	6.271	5.759	2.444	2.139	0.894	0.336	0.304	0.197	0.437	1.354	2.429
1901	0.803	0.551	4.205	7.711	4.222	1.525	0.738	0.792	0.495	1.001	0.799	5.002
1902	2.579	2.168	6.176	3.341	1.595	0.635	0.452	0.459	0.372	1.471	0.982	2.859
1903	1.957	3.300	5.297	3.463	0.880	3.297	0.966	0.734	0.580	1.065	0.981	1.476
1904	1.020	1.434	4.653	4.617	2.317	1.179	0.769	0.549	0.764	0.538	0.530	0.680
1905	1.959	0.700	4.648	2.502	0.688	0.838	0.565	0.497	1.900	0.567	0.684	1.575
1906	1.757	1.588	2.878	3.263	2.371	1.831	1.127	0.915	0.428	0.820	1.160	1.229
	1.819	2.167	4.696	3.823	1.951	1.418	0.825	0.805	0.670	0.899	1.250	2.252

TABLE No. 14.

South Branch Nashua River at Clinton. 119 Square Miles.

Monthly flows in second-feet per square mile arranged in order of magnitude by years.

	1	2	3	4	5	6	7	8	9	10	11	12
1897	0.377	0.528	1.232	1.386	1.440	1.800	1.828	1.984	2.231	2.525	3.521	4.270
1898	0.514	1.045	1.281	2.049	2.151	2.334	2.418	2.530	3.137	3.189	3.358	4.778
1899	0.365	0.379	0.387	0.548	0.555	0.665	0.869	1.344	1.687	3.236	4.295	5.224
1900	0.197	0.304	0.336	0.437	0.894	1.232	1.354	2.139	2.429	2.444	5.759	6.271
1901	0.495	0.551	0.738	0.792	0.799	0.803	1.001	1.525	4.205	4.222	5.002	7.711
1902	0.372	0.452	0.459	0.635	0.982	1.471	1.595	2.168	2.579	2.859	3.341	6.176
1903	0.580	0.734	0.880	0.966	0.981	1.065	1.476	1.957	3.297	3.300	3.463	5.297
1904	0.530	0.538	0.549	0.680	0.764	0.769	1.020	1.179	1.434	2.317	4.617	4.653
1905	0.497	0.565	0.567	0.684	0.688	0.700	0.838	1.575	1.900	1.959	2.502	4.648
1906	0.428	0.820	0.915	1.127	1.160	1.229	1.588	1.751	1.831	2.371	2.878	3.263
	0.436	0.592	0.734	0.930	1.041	1.207	1.399	1.815	2.473	2.842	3.874	5.229

TABLE No. 15.

SOUTH BRANCH NASHUA RIVER AT CLINTON.

Monthly flows in second-feet per square mile arranged in order of magnitude of whole term, regardless of the years.

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.197	0.452	0.551	0.700	0.869	1.065	1.386	1 751	2.151	2.525	3.300	4.648
2	0.304	0.459	0.555	0.734	0.880	1.127	1.434	1.800	2.168	2.530	3.341	4.653
3	0.336	0.495	0.565	0.738	0.894	1.160	1.440	1.828	2.231	2.579	3.358	4.778
4	0.365	0.497	0.567	0.764	0.915	1.179	1.471	1.831	2.317	2.859	3.463	5.002
5	0.372	0.514	0.580	0.769	0.966	1.229	1.476	1.900	2.334	2.878	3.521	5.224
6	0.377	0.528	0.635	0.792	0.981	1.232	1.525	1.957	2.371	3.137	4.205	5.297
7	0.379	0.530	0.665	0.799	0.982	1.232	1.575	1.959	2.418	3.189	4.222	5.759
8	0.387	0.538	0.680	0.803	1.001	1.281	1.588	1.984	2.429	3.236	4.270	6.176
9	0.428	0.548	0.684	0.820	1.020	1 344	1.595	2.049	2.444	3.263	4.295	6.271
10	0.437	0.549	0.688	0.838	1.045	1.354	1.687	2.139	2.502	3.297	4.617	7.711
	0.358	0.511	0.617	0.776	0.955	1.220	1.518	1.920	2.336	2.949	3.859	5.552

TABLE No. 16.

NASHUA RIVER AT CLINTON. 119 SQUARE MILES.

Comparison of available flow averaged by three different methods.

CHRONOLOGICALLY.			ORDER OF MAGNITUDE BY YEARS.			ORDER OF MAGNITUDE OF WHOLE TERM.		
Month.	Flow.	Flow Available.	No.	Flow.	Flow Available.	No.	Flow.	Flow Available.
September.....	0.669	0.669	1	0.436	0.436	1	0.358	0.358
August.........	0.805	0.794	2	0.592	0.579	2	0.511	0.498
July...........	0.824	0.809	3	0.734	0.697	3	0.617	0.587
October........	0.899	0.866	4	0.930	0.844	4	0.776	0.706
November	1.250	1.100	5	1.041	0.918	5	0.955	0.825
June..........	1.418	1.198	6	1.207	1.015	6	1.220	0.980
January.......	1.819	1.398	7	1.399	1.111	7	1.518	1.129
May	1.951	1.453	8	1.815	1.285	8	1.920	1.296
February......	2.167	1.525	9	2.473	1.504	9	2.337	1.436
December	2.251	1.546	10	2.842	1.596	10	2.949	1.580
April	3.823	1.808	11	3.874	1.768	11	3.859	1.740
March	4.696	1.881	12	5.229	1.881	12	5.552	1.881

TABLE No. 17.

MERRIMAC RIVER AT LAWRENCE. DRAINAGE AREA, 4 452 SQUARE MILES.

1890 to 1896. Weekly data arranged in order of magnitude for full term in second-feet per square mile.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.271	0.386	0.414	0.434	0.459	0.476	0.491	0.500	0.515	0.534	0.548	0.565	0.581	0.602	0.615	0.640	0.663	0.689
2	0.284	0.387	0.415	0.434	0.461	0.477	0.491	0.501	0.516	0.534	0.549	0.565	0.581	0.602	0.617	0.641	0.663	0.692
3	0.325	0.390	0.415	0.437	0.461	0.477	0.492	0.501	0.517	0.535	0.550	0.566	0.582	0.604	0.618	0.642	0.665	0.692
4	0.335	0.393	0.416	0.437	0.461	0.479	0.492	0.502	0.519	0.536	0.551	0.568	0.583	0.604	0.619	0.644	0.665	0.693
5	0.339	0.394	0.418	0.439	0.463	0.480	0.493	0.505	0.519	0.536	0.553	0.569	0.584	0.604	0.621	0.644	0.666	0.694
6	0.342	0.396	0.419	0.440	0.465	0.482	0.493	0.505	0.521	0.536	0.553	0.570	0.589	0.605	0.624	0.645	0.668	0.695
7	0.344	0.396	0.420	0.440	0.466	0.482	0.493	0.505	0.521	0.536	0.553	0.570	0.591	0.607	0.624	0.645	0.669	0.699
8	0.345	0.397	0.422	0.440	0.466	0.482	0.494	0.506	0.524	0.536	0.555	0.571	0.591	0.607	0.625	0.648	0.672	0.701
9	0.359	0.399	0.422	0.441	0.466	0.483	0.494	0.508	0.524	0.539	0.555	0.573	0.597	0.607	0.626	0.652	0.673	0.704
10	0.364	0.401	0.423	0.444	0.467	0.487	0.494	0.508	0.525	0.541	0.555	0.574	0.597	0.608	0.626	0.654	0.676	0.706
11	0.368	0.403	0.423	0.446	0.467	0.487	0.495	0.508	0.525	0.541	0.556	0.574	0.598	0.609	0.629	0.655	0.677	0.706
12	0.369	0.405	0.423	0.447	0.468	0.488	0.495	0.508	0.526	0.542	0.556	0.575	0.600	0.613	0.629	0.655	0.679	0.707
13	0.372	0.405	0.424	0.449	0.469	0.489	0.496	0.512	0.529	0.543	0.557	0.575	0.600	0.613	0.634	0.656	0.681	0.707
14	0.374	0.406	0.430	0.451	0.469	0.489	0.498	0.513	0.530	0.544	0.557	0.578	0.601	0.614	0.635	0.657	0.685	0.710
15	0.380	0.406	0.431	0.455	0.470	0.490	0.498	0.514	0.532	0.546	0.557	0.578	0.601	0.614	0.636	0.659	0.686	0.711
16	0.383	0.409	0.432	0.457	0.470	0.490	0.499	0.514	0.533	0.546	0.560	0.578	0.601	0.614	0.636	0.660	0.687	0.712
17	0.385	0.411	0.432	0.458	0.472	0.491	0.500	0.515	0.533	0.548	0.564	0.579	0.601	0.615	0.639	0.660	0.688	0.715
Average,	0.349	0.399	0.422	0.444	0.466	0.484	0.494	0.507	0.524	0.540	0.555	0.572	0.593	0.608	0.627	0.650	0.674	0.702

TABLE No. 18.

MERRIMAC RIVER AT LAWRENCE. DRAINAGE AREA, 4 452 SQUARE MILES.

1890 to 1906. Weekly data arranged in order of magnitude for full term.

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.716	0.743	0.763	0.790	0.826	0.865	0.899	0.934	0.991	1.045	1.114	1.160	1.231	1.300	1.355	1.420	1.485	1.577
2	0.720	0.743	0.764	0.792	0.837	0.865	0.900	0.935	0.994	1.046	1.118	1.161	1.234	1.302	1.359	1.421	1.486	1.577
3	0.721	0.744	0.766	0.794	0.839	0.867	0.902	0.947	0.999	1.053	1.121	1.161	1.235	1.307	1.367	1.423	1.486	1.580
4	0.721	0.744	0.772	0.795	0.841	0.869	0.902	0.951	1.000	1.054	1.123	1.163	1.244	1.313	1.367	1.429	1.490	1.583
5	0.722	0.745	0.773	0.795	0.845	0.870	0.903	0.953	1.001	1.067	1.126	1.169	1.249	1.313	1.370	1.430	1.493	1.590
6	0.722	0.745	0.773	0.795	0.847	0.874	0.903	0.966	1.004	1.073	1.127	1.173	1.251	1.316	1.375	1.433	1.502	1.590
7	0.724	0.751	0.774	0.800	0.848	0.878	0.910	0.968	1 007	1.079	1.130	1.181	1.252	1.316	1.387	1.438	1.504	1.592
8	0.726	0.752	0.775	0.802	0.849	0.879	0.910	0.971	1.009	1.083	1.135	1.195	1.260	1.319	1.394	1.442	1.517	1.595
9	0.726	0.753	0.780	0.802	0.853	0.886	0.911	0.972	1.015	1.086	1.138	1 197	1.268	1.319	1.394	1.443	1.519	1.596
10	0.727	0.755	0.780	0.807	0.855	0.886	0.913	0.972	1.017	1.092	1.142	1.198	1.272	1.319	1.398	1.444	1.530	1.597
11	0.729	0.756	0.781	0.809	0.858	0.888	0.915	0.973	1.025	1.095	1.142	1.204	1.275	1.319	1.400	1.452	1.532	1.600
12	0.729	0.756	0.781	0.809	0.859	0.888	0.925	0.974	1.029	1.098	1.143	1.204	1.287	1.327	1.412	1 457	1.536	1.604
13	0.730	0.756	0.783	0.809	0.859	0.888	0.925	0.977	1.034	1.098	1.144	1.208	1.291	1.328	1.413	1.458	1.545	1.608
14	0.731	0.757	0.783	0.810	0.861	0.889	0.928	0.980	1.035	1.101	1.148	1.210	1.292	1.333	1.414	1.477	1.545	1.608
15	0.731	0.758	0.784	0.813	0.863	0.891	0.928	0.985	1.036	1.108	1.148	1.211	1.295	1.335	1.414	1.477	1.548	1.615
16	0.733	0.759	0.788	0.821	0.864	0.894	0.928	0.989	1.039	1.110	1.149	1.218	1.296	1.344	1.416	1.477	1.548	1.619
17	0.740	0.760	0.788	0.825	0.864	0.895	0.929	0.991	1.041	1.110	1.157	1.222	1.296	1.353	1.417	1.485	1.569	1.622
Average	0.726	0.752	0.777	0.804	0.851	0.881	0.914	0.961	1.016	1.082	1.136	1.190	1.266	1.321	1.391	1.447	1.520	1.597

TABLE No. 19.

MERRIMAC RIVER AT LAWRENCE. DRAINAGE AREA, 4 452 SQUARE MILES.

1890 to 1906. Weekly data arranged in order of magnitude for full term.

	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
1	1.626	1.785	1.895	2.017	2.128	2.280	2.431	2.565	2.786	3.017	3.323	3.639	4.199	4.519	5.088	5.765
2	1.634	1.802	1.902	2.019	2.133	2.283	2.432	2.568	2.823	3.053	3.356	3.661	4.217	4.562	5.095	5.908
3	1.634	1.804	1.903	2.026	2.169	2.289	2.440	2.571	2.830	3.084	3.384	3.681	4.244	4.565	5.111	5.941
4	1.639	1.825	1.928	2.048	2.173	2.294	2.443	2.598	2.832	3.092	3.389	3.683	4.261	4.608	5.122	6.310
5	1.686	1.831	1.929	2.049	2.202	2.319	2.457	2.619	2.853	3.096	3.415	3.690	4.278	4.636	5.168	6.364
6	1.687	1.833	1.929	2.050	2.203	2.322	2.461	2.631	2.865	3.103	3.424	3.747	4.291	4.637	5.242	6.426
7	1.697	1.846	1.935	2.055	2.204	2.350	2.472	2.676	2.891	3.119	3.433	3.762	4.300	4.681	5.267	6.436
8	1.701	1.851	1.941	2.056	2.205	2.371	2.473	2.687	2.915	3.123	3.445	3.835	4.320	4.701	5.270	6.470
9	1.702	1.858	1.943	2.060	2.217	2.372	2.486	2.701	2.930	3.124	3.446	3.894	4.339	4.718	5.274	6.767
10	1.708	1.861	1.946	2.075	2.226	2.376	2.502	2.714	2.953	3.134	3.454	3.942	4.342	4.723	5.307	7.260
11	1.716	1.874	1.969	2.077	2.231	2.377	2.507	2.723	2.955	3.147	3.476	3.944	4.375	4.723	5.335	7.361
12	1.718	1.883	1.969	2.078	2.231	2.388	2.508	2.726	2.982	3.148	3.478	3.950	4.378	4.734	5.340	7.891
13	1.725	1.885	1.981	2.091	2.239	2.391	2.509	2.729	2.986	3.150	3.481	3.966	4.468	4.837	5.387	7.900
14	1.734	1.889	1.990	2.098	2.246	2.392	2.530	2.735	3.005	3.193	3.493	3.969	4.469	4.884	5.392	8.237
15	1.759	1.890	1.993	2.104	2.254	2.394	2.531	2.746	3.014	3.231	3.510	3.981	4.471	5.007	5.530	8.622
16	1.764	1.892	2.005	2.115	2.259	2.400	2.539	2.751	3.014	3.234	3.520	4.060	4.475	5.044	5.585	9.036
17	1.781	1.895	2.014	2.116	2.270	2.406	2.558	2.781	3.015	3.303	3.529	4.168	4.511	5.061	5.725	9.043
Av.	1.701	1.853	1.951	2.067	2.211	2.353	2.487	2.678	2.921	3.138	3.444	3.857	4.349	4.744	5.308	7.161

TABLE No. 20.

MERRIMAC AT LAWRENCE. 1890 TO 1906.

Second-feet per square mile.

Development.	Average Available.	Weeks.		Available per ct. of Development.
		Short.	Full.	
0.3	0.300	0	52	100
0.4	0.399	2	50	100
0.5	0.492	7	45	98
0.6	0.572	13	39	95
0.7	0.642	17	35	92
0.8	0.705	21	31	88
0.9	0.762	24	28	85
1.0	0.813	26	26	81
1.1	0.861	28	24	78
1.2	0.906	30	22	76
1.3	0.947	31	21	73
1.4	0.986	33	19	70
1.5	1.022	34	18	68
1.6	1.055	36	16	66
1.7	1.085	36	16	64
1.8	1.114	37	15	62
1.9	1.142	38	14	60
2.0	1.168	39	13	58
2.1	1.193	40	12	57
2.2	1.215	41	11	55
2.3	1.236	41	11	54
2.4	1.256	42	10	52
2.5	1.275	43	9	51
2.6	1.292	43	9	50
2.7	1.309	44	8	48
2.8	1.325	44	8	47
2.9	1.340	44	8	46
3.0	1.354	45	7	45
3.1	1.367	45	7	44
3.2	1.380	46	6	43
3.3	1.391	46	6	42
3.4	1.400	46	6	41
3.5	1.413	47	5	40
3.6	1.423	47	5	39
3.7	1.432	47	5	38
3.8	1.442	47	5	37
3.9	1.451	48	4	37
4.0	1.458	48	4	36
4.1	1.466	48	4	36
4.2	1.474	48	4	35
4.3	1.482	48	4	35
4.4	1.488	49	3	34
4.5	1.494	49	3	33
4.6	1.500	49	3	33
4.7	1.506	49	3	32
4.8	1.510	50	2	32
4.9	1.514	50	2	31
5.0	1.518	50	2	30

A GLANCE AT THE WATER SUPPLY OF PHILADELPHIA.

BY JOHN C. TRAUTWINE, JR., CIVIL ENGINEER, PHILADELPHIA, PENN.

[*Read September 23, 1903.*]

INTRODUCTION.

Now that the New England Water Works Association has ventured so far out of its latitude as to hold its convention in a suburb of Philadelphia, it seems not inappropriate that some mention should be made of a water-works enterprise the inception and progress of which have greatly exercised some of the inhabitants of that city.

I have been asked to present a statement of the "progress and present condition" of the Philadelphia filtration plant; but, in order to do this satisfactorily, it may be well to give, first, an outline of the works in general.

With the same object in view, I find myself tempted to volunteer also a bit of the *history* of the Philadelphia water supply, even at the risk of indulging in some personal reminiscences, and thus fighting some of my own battles o'er again.

EARLY CONDITIONS.

The public water supply of Philadelphia has always been drawn either from the Schuylkill River alone or from the Schuylkill and Delaware rivers, the Schuylkill being a tributary of the Delaware and entering that stream at the lower end of the city.

The Schuylkill rises in the anthracite coal regions of Pennsylvania, about 100 miles above Philadelphia, and has a watershed of about 1 900 square miles. The Delaware rises in the southeastern part of New York state, a little north of Port Jervis, where New York, New Jersey, and Pennsylvania meet. Its watershed, above Philadelphia, has about 8 000 square miles, and is about 180 miles long, from north to south, and in general from 20 to 70 miles wide from east to west.

Prior to 1854 the city of Philadelphia covered only about two square miles, being comprised within the nearly rectangular area bounded by the Delaware River on the east, by the Schuylkill

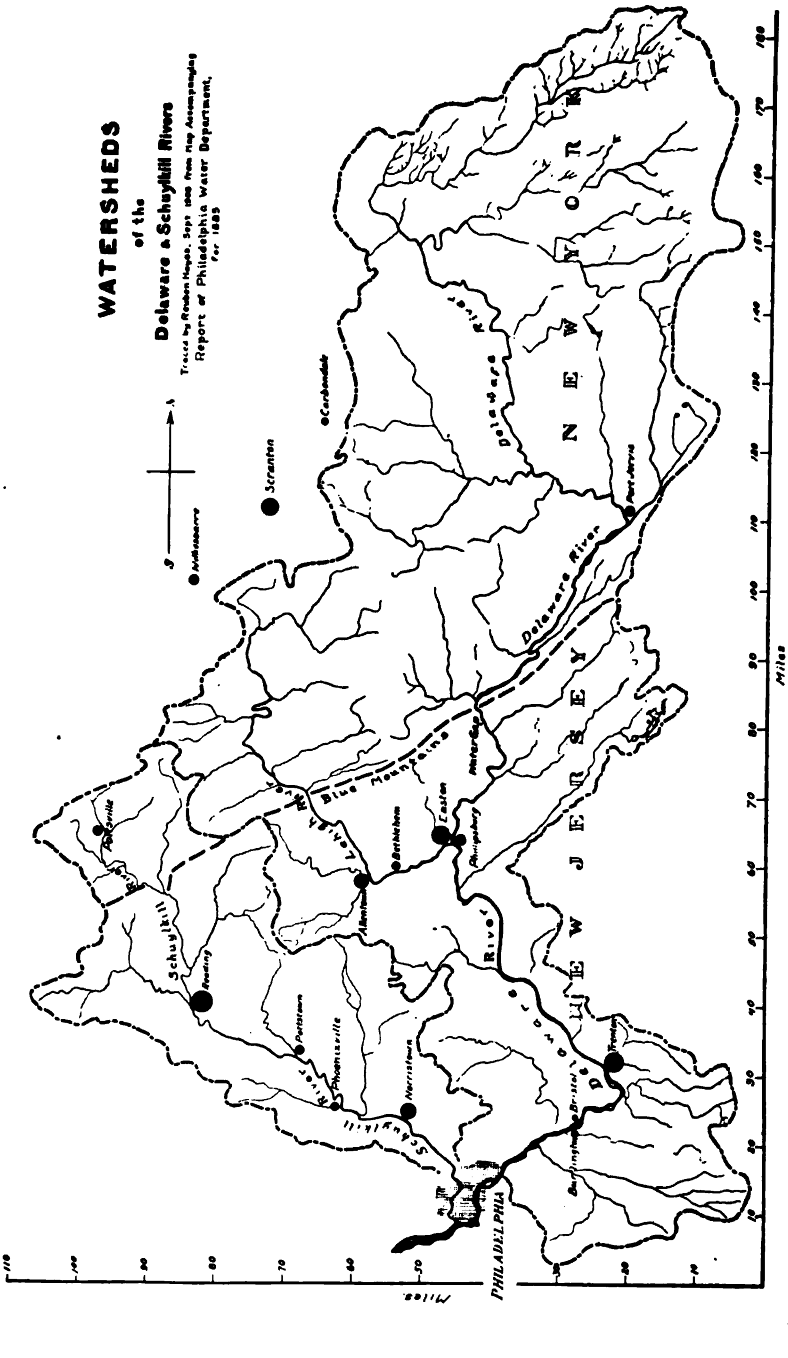

WATERSHEDS
of the
Delaware & Schuylkill Rivers
Report of Philadelphia Water Department,
Scranton
Carbondale
Delaware River
Blue Mountains
Water Gap
Schuylkill
Reading
Pottstown
Phoenixville
Norristown
Allentown
Bethlehem
Easton
Phillipsburg
Port Jervis
Trenton
Bristol
Burlington
PHILADELPHIA
N E W Y O R K
N E W J E R S E Y
Miles

FIG. 1.

River on the west, by Vine Street on the north, and (appropriately) by South Street on the south. The distance between rivers is about two miles, and the distance between Vine and South streets is about one mile. Beyond these limits lay the " districts " of Kensington, Northern Liberties, Spring Garden, etc., on the north; Southwark, Moyamensing, etc., on the south.

About the close of the eighteenth century, say 1795 to 1800, the city was repeatedly scourged by yellow fever, which drove its well-to-do inhabitants to the adjacent hills or to distant places and left the poor in town to bear it as best they could.

Even in those early days, some connection was suspected between the water supply and the spread of such diseases, for these visitations of yellow fever gave rise to active agitation for an improved and public water supply, the supply hitherto having been taken from wells and cisterns.

Scott's Geographical Dictionary, published in 1805, says: " The water of those parts of the city which are most thickly inhabited . . . had become so corrupt by the multitude of sinks and other receptacles of impurity, as to be almost unfit to be drank."

As in later days, all manner of rival schemes were brought forward and were soon in lively conflict. Among these stood out prominently the proposition of the Delaware and Schuylkill Canal Company, which proposed to tap the Schuylkill River at Norristown, fourteen miles above the city, and to construct a navigation canal from that point down the east bank of the Schuylkill River to Fairmount, and thence across the country, just north of the city, to the Delaware. This concern proposed to tap its main canal at Broad Street and to bring a branch canal, for water supply, to a pond or reservoir to be constructed on " Broad Street extended," at what is now Callowhill Street, just north of the then city limits, whence another canal was to lead down Broad Street, across the city, to South Street, and to supply canals, or at least gutters, on the east and west streets. This was to be a gravity supply, in the true and extreme sense of the word, the citizens being expected to take their supplies by main force from these surface canals. In the canal company's proposition, the introduction of a supply under pressure was reserved for future discussion.

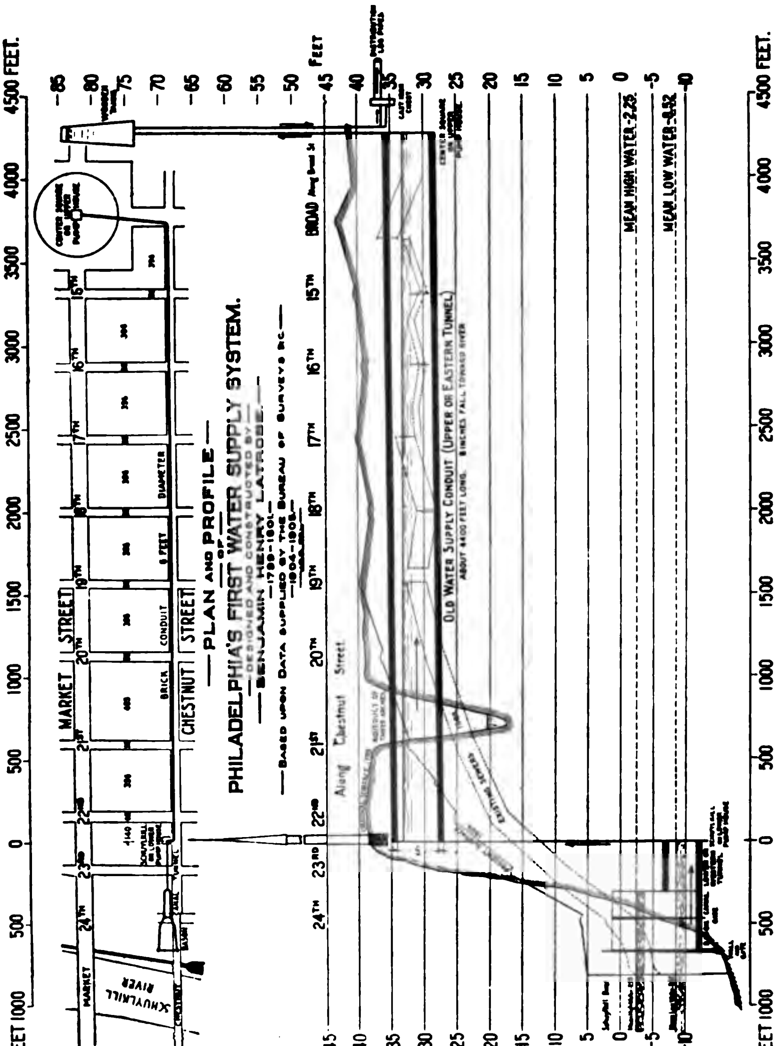


Fig. 2. Philadelphia's First Water Supply System.
Devised and Constructed by Benjamin Henry Latrobe, 1799-1801.
Plan and Profile.

Another prominent project was that of Benjamin Franklin, who left a sum of money to be expended in bringing the waters of the Wissahickon Creek to the city.

Finally, however, the project of Benjamin Henry Latrobe (who

refers to himself as being " the only successful architect and engineer " in America at that time) prevailed and was carried to execution in 1801. (See portrait, Plate I.)

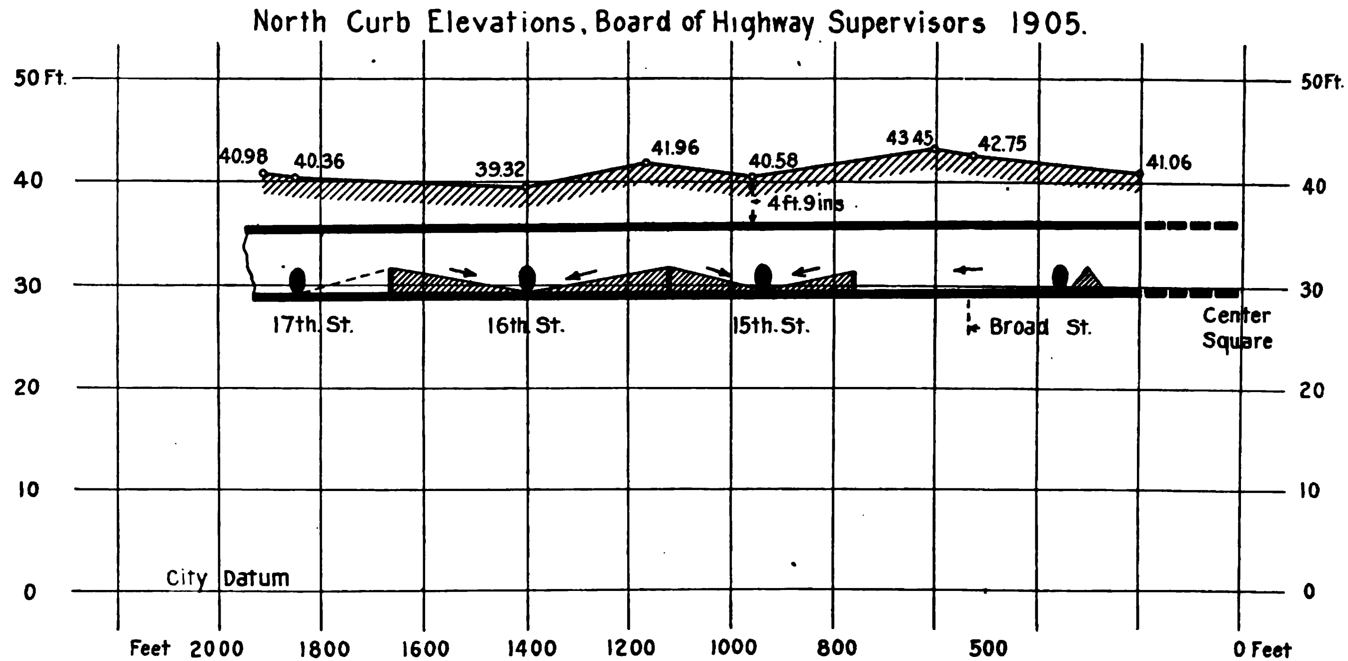
The Schuylkill was tapped on the east side, at Chestnut Street, and its waters were led, by gravity, to the pump well of a steam station located upon the site of a British redoubt, on high ground on the north side of Chestnut Street, just west of Twenty-Second Street, or about one block east of Chestnut Street bridge. (Plate II, Fig. 1.) Here the surplus power of the engine was rented out to run a rolling and slitting mill in an adjacent building.

This station lifted the water into a six-foot brick conduit, which ran along the north side of Chestnut Street to Broad Street, and there turned abruptly and ran northward to a second station in Center Square, the site of the present City Hall. Here the water was again pumped, this time into overhead tanks, whence it flowed through log pipes to the distribution. (See Fig. 2, and Plates II and III.)

West of about Seventeenth or Eighteenth Street, the grading down of Chestnut Street has removed the old conduit, but east of Seventeenth Street it is still in place. During comparatively recent years it has been used for purposes of sewerage, a low dam being constructed across it, about the middle of each block, and false bottoms placed in it, sloping each way from the dams to the sewers on the north-and-south streets at the ends of the block, as shown in Fig. 3. The conduit (so much as remained of it) was thus made to serve as a series of short feeders to the sewers running north and south. In April, 1906, the old conduit was cut through, where the City Hall looks down South Broad Street, by the excavations for the subway since constructed.

In a report to the American Philosophical Society, in 1803, Latrobe mentions the two engines of the Philadelphia system, two in New York, and one in Boston, five in all, as being " the only engines of any considerable powers which, as far as I know, are now at work in America." This enables us to form some idea of the prodigiousness of the work involved in the tiny first waterworks of Philadelphia.

The earliest boilers were of wood, but these were shortly followed by cast iron, and afterward by plate iron boilers. The prin-



OLD 6 FT. BRICK AQUEDUCT IN BROAD AND CHESTNUT ST'S. AS USED FOR SEWERAGE.

FIG. 3.

PLATE I.

BENJAMIN HENRY LATROBE,

Engineer of Philadelphia's first Water Works, 1799–1801.

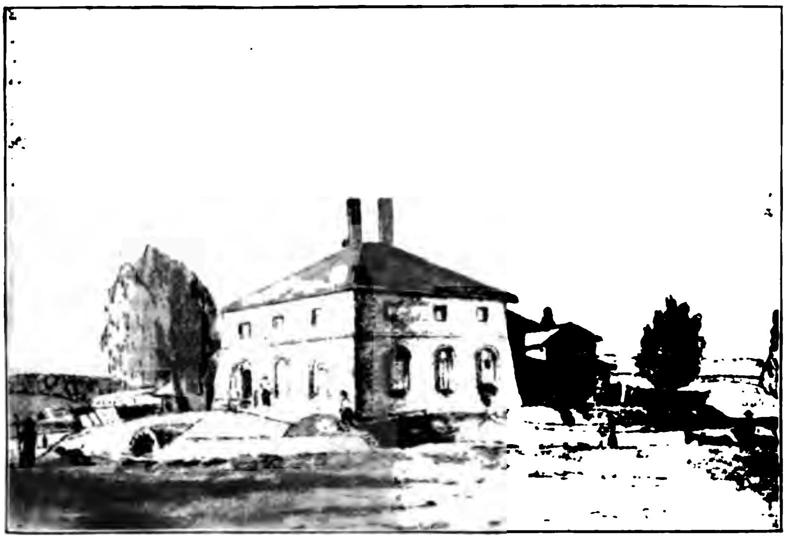
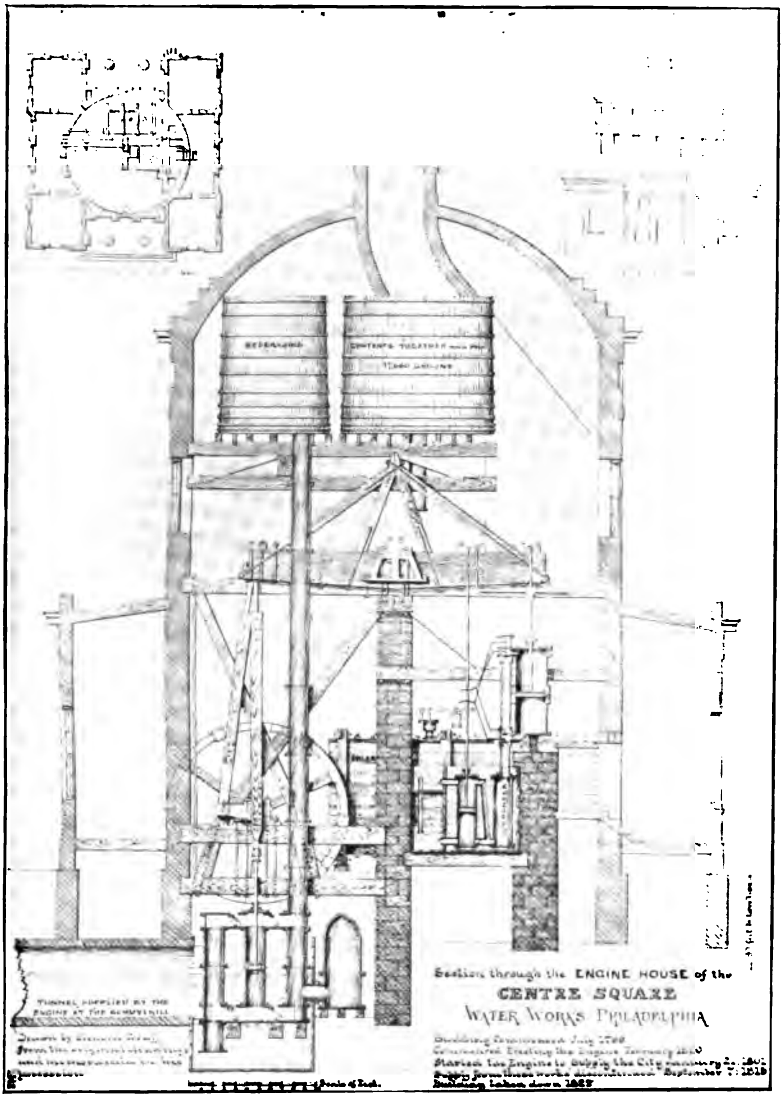


FIG. 1. SCHUYLKILL PUMPING STATION, PHILADELPHIA.
BUILT 1799–1801.

(From a water-color sketch by Mumford.)

FIG. 2. CENTER SQUARE PUMPING STATION, PHILADELPHIA.
Built 1799–1801, on site of present City Hall, Broad and Market streets. Removed 1827.



CENTER SQUARE PUMP HOUSE, PHILADELPHIA. 1799–1801.
VERTICAL SECTION.

(The distortion of the two upper figures is due to unavoidable difficulties in photographing.)

cipal rods, beams, and shafts of the engines were also of wood, as were also the tanks, and, as we have seen, the distributing pipes. Some of the details of these boilers and engines are shown in Fig. 4.

The contractor for the engines was Nicholas I. Roosevelt, of Soho, N. J., a brother to President Roosevelt's grandfather. Nicholas, who afterward married Latrobe's daughter, was evidently a heavy loser through the contract, and the city suffered correspondingly, the " Watering Committee " finding it impossible to keep him up to time with his work. In particular, Mr. Roosevelt undertook to provide the Schuylkill engine with an " index " (probably a revolution counter). One annual report after another remarks that this " index " is not yet in place, and finally the mention of it is dropped. (See portrait, Plate IV.)

On the other hand, the city councils, then as now, found it possible to act the part of a thorn in the flesh of the engineer. Nicholas was practically bankrupted by delays in payments, and in one of his letters Latrobe writes, " First the sub-committee of the Watering Committee must assent to an agreement, then comes the Watering Committee itself, then the Common Council and the Select Council, — all avaricious, unjust, ignorant, and proud."

These first water works were completed and put in operation in 1801, but they gave most unsatisfactory service; and, the conditions having become intolerable, the old pumping stations and the conduit were abandoned in 1815, and the same distribution system was supplied by steam pumps (including one by Oliver Evans) at Fairmount, which pumped into a reservoir on the top of the rocky Fairmount hill. This reservoir, since greatly enlarged, but still one of the smaller reservoirs, and the old steam pump house, are still standing.

About 1820, a dam and breast wheels were constructed at Fairmount and the steam engines at that point abandoned.

The Fairmount works were constructed by Fred. Graff, Sr. (see portrait, Plate IV), who had been Latrobe's assistant from the beginning, and who was for many years in charge of the water works, as was his son, Fred. Graff, Jr., after him.

At the time of their completion, the Fairmount water works were one of the wonders of the world, and most of my contemporaries

Figures accompanying "First Report of Benjamin H. Latrobe, to the American Philosophical Society, held at Philadelphia; in answer to the enquiry of the Society of Rotterdam, 'Whether any, and what improvements have been made in the construction of Steam-engines in America.'"

American Philosophical Transactions
Vol. 6, pp. 89 &c

May 20, 1803.

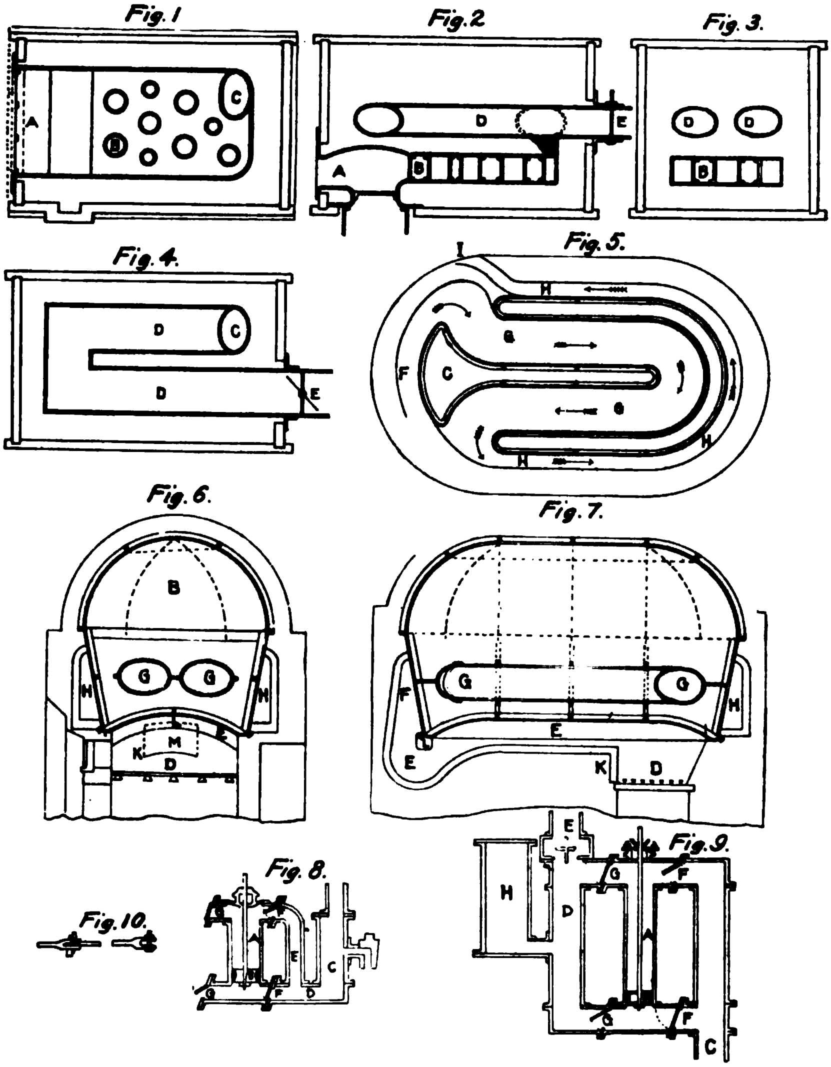


FIG. 4. BOILERS AND ENGINES, PHILADELPHIA'S FIRST WATER WORKS, 1799–1801.

(See opposite page for description of figures.)

will remember how they figured, along with Girard College, in the descriptions of Philadelphia in the school geographies, even as late as the fifties.

In 1851 the first turbine was constructed at Fairmount, and this remained the only turbine until 1867, between which and 1874 all the breast wheels were abandoned and succeeded by six new turbines, making seven in all. This Fairmount plant supplied the entire city proper between Vine and South streets, and, under contract, some portions of the adjacent districts.

In 1854 the city increased its area from 2 to 130 square miles (its present dimensions) by taking in the outlying "districts" and all the rest of Philadelphia County, making the city and county coterminous.

In the meantime, the adjacent districts of Kensington and Spring Garden had constructed steam pumping stations of their own, the Kensington works taking water from the Delaware, and the Spring Garden works from the Schuylkill. With consolidation, these works were taken over by the city, and thereafter the water supply system of the consolidated city grew rapidly.

RECENT CONDITIONS.

Prior to the inauguration of the present filtration system, that is to say, about ten years ago, the works consisted of six pumping stations, five on the Schuylkill and one on the Delaware, those on the Schuylkill being located on the east, or left, bank of the river, except the Belmont station, which supplied that portion of the city lying west of the river. About 90 per cent. of all the water pumped was then taken from the smaller stream, the Schuylkill.

DESCRIPTION OF SMALL FIGURES MAKING UP FIG. 4.

FIGS. 1, 2, 3, 4. Wooden Boilers.
- Fig. 1. Horizontal section through A B, Fig. 2.
- Fig. 2. Vertical longitudinal section at A, Fig. 1.
- Fig. 3. Vertical cross section at D, Fig. 2.
- Fig. 4. Horizontal section through D, Fig. 2.

FIGS. 5, 6, 7. Cast Iron Boilers.
- Fig. 5. Horizontal section through G, Fig. 7.
- Fig. 6. Vertical cross section through G, Fig. 7.
- Fig. 7. Vertical longitudinal section through B D, Fig. 6.

FIG. 8. Air Pump, double acting.
FIG. 9. Main Pump, water end, double acting.
FIG. 10. Braces for cast-iron boilers.

All of the stations, except the one at Fairmount, were operated by steam, and all pumped normally to open, elevated reservoirs, whence the water flowed, by gravity, into the distribution.

It frequently happened, however, that the pumps were unable to keep the reservoirs supplied against the enormous draft (due partly to the use of water, but much more largely to waste), and at such times it became necessary to cut off the reservoirs and to resort to direct pumpage. The dirty river water was then sent direct into our dwellings, without even the benefit of a day or two of sedimentation.

There were also three or four high-service stations, pumping to standpipes, and supplying small districts at elevations too high to be reached by the main pumping stations or supplied from the reservoirs.

The Roxborough station, that farthest up the Schuylkill, raised its water to an elevation of about 400 feet; the Fairmount, or lowest station, about 100 feet.

The Schuylkill river flows through prosperous agricultural and manufacturing districts, with numerous large and thriving manufacturing towns along its banks; so that, although cut off, by the Fairmount dam, from the major part of the city's own pollution, its waters had, long before the present filtration works were designed, become wholly unfit for household use, to say nothing of the fact that each flood in the river brought down, first, the new red shale mud from the districts near the city, and, a day or two later, the anthracite coal dust which had been stored in the navigation dams in the upper portion of the stream.

The Delaware, on the other hand, a larger stream, and flowing through a less densely populated district, was unprotected, by any dam, from the city's own pollution, which traveled upstream with every flood tide.

Notwithstanding this, no attempt at purification of the water had been made. The entire city was supplied with the same fluid which is now furnished to the central business and residence districts. With my apologies to those good people who hold that we should speak only good of our own town, I venture to assert that the conditions were ripe for improvement.

PLATE IV.

NICHOLAS I. ROOSEVELT, BROTHER OF PRESIDENT ROOSEVELT'S GRANDFATHER, AND BUILDER OF THE TWO STEAM PUMPING ENGINES OF PHILADELPHIA'S FIRST WATER WORKS.

FREDERICK GRAFF, ASSISTANT TO B. H. LATROBE, AND AFTERWARD CHIEF ENGINEER OF PHILADELPHIA WATER WORKS.

He designed and built the steam-power, and, later, the water-power works at Fairmount.

FIG. 1. FAIRMOUNT WATER WORKS, PHILADELPHIA.

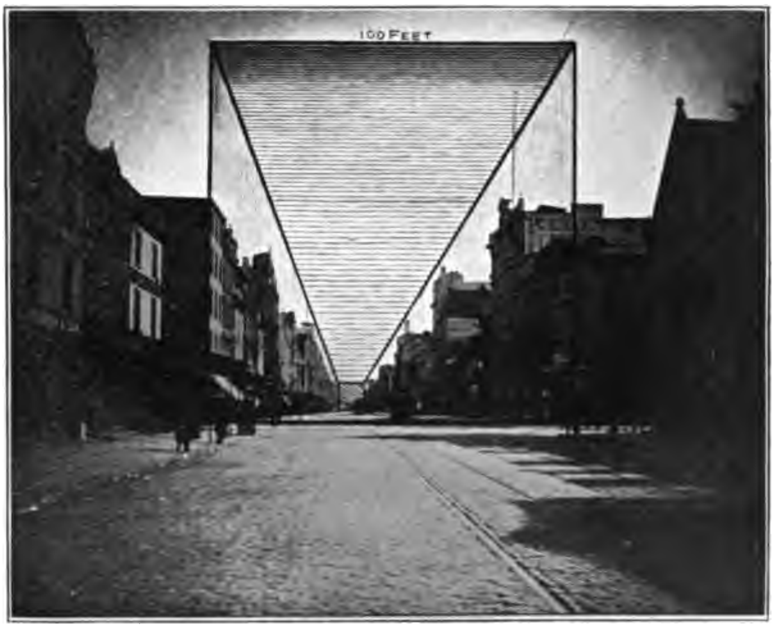


FIG. 2. 250 MILLION GALLONS.
(100 feet square, 3,300 feet long.)
MARKET STREET, LOOKING EAST FROM SEVENTH STREET TO DELAWARE RIVER.

Not only was the quality of the water atrocious, but the supply was ridiculously inadequate, and that solely because the people gloried in throwing away, unused, at least two thirds of all the water pumped.

With the greatest water-pumping plant on earth, running night and day, straining itself to the point of destruction, and pumping something like two hundred gallons per capita daily, a large portion of the city was constantly complaining (and with excellent cause) of the insufficiency of the supply, — the pressure, over much of the area, being insufficient to carry the water above the second floor; and all because one man in five was robbing the other four, and the four insisted that the robber should not be interfered with.

The average pumpage, deduced from plunger displacement and no doubt considerably exaggerated, was about 250,000 000 gallons per day. Even allowing for exaggeration, it probably approximated at least 200 000 000 gallons.

Market Street is one hundred feet wide between house-lines; and 250 000 000 gallons would fill Market Street, to a depth of one hundred feet, from the Delaware river to 7th Street, forming a square prism one hundred feet square and three thousand feet long, as shown on Plate V, Fig. 2.

During the agitation respecting the method of improvement of the water supply, a certain homeopathic physician, apparently well informed on many subjects, remarked, in one of his discourses in eulogy of the scheme in question, that " the people of Philadelphia would never submit to having their water doled out to them by the pint."

In order to show what ballast there was in this learned remark, I had three cubical frames prepared, covered with white muslin, and photographed. The largest of these frames was a 10-foot cube, containing, therefore, 1 000 cubic feet, which the city was then selling, by meter, for " thirty cents "; the next contained 1 000 gallons, or four cents' worth, while the smallest contained 1 000 pints, or one cent's worth. These 1 000 pints will furnish six comfortable baths.

In those degenerate days, our city fathers, and the statesmen who controlled the city's operations, were intent chiefly upon

obtaining and holding the control of things, and the sanitary condition of the city was a matter of quite secondary importance.

Although communities all about us were loudly proclaiming the benefits to be derived from the use of the water meter, our people were so densely and persistently ignorant of the matter that those who were most actively but unofficially interested in the improvement of the water supply, were ready to suppress abruptly any one who mentioned the water meter, and thereby threatened to arouse public opposition to the whole scheme of water improvement.

Under the circumstances, it is not strange that there was lively agitation for improvement. Commission after commission had studied the subject and made recommendations, most or all of which were ignored; and, as happened a hundred years before, all manner of rival schemes were actively advocated.

At this juncture, the writer found himself in charge of the Bureau of Water. He gave careful study to the subject of the improvement of the supply, both as to quantity and as to quality.

As to quantity, the result of course was that he persistently advocated the use of the water meter, and thereby not only alienated the politicians, who saw their welfare rather in the construction of unlimited pumps and "resavoys," but also lost the sympathy and coöperation of the public-spirited people who were forming themselves into associations for water improvement, and who were fearful lest all projects for improvement would be dashed by the mention of the ominous word "meter"; and this notwithstanding the fact that the city's finances at that time were (or were given out to be) such that the city could not possibly find means for the construction of works for the purification of the enormous quantities then used and wasted.

As to quality, the writer's studies had impressed him most forcibly with the facts (1) that filtration was the indicated solution of our problem; and (2) that the science of water purification was then in its infancy, that each supply must, to a great extent, be a law unto itself, and that each community must work out its own salvation with fear and trembling, and without relying slavishly upon the experiences of other communities.

He recognized, too, that the Philadelphia system lent itself admirably to just such experimental work as was required in its case, where the supply was taken from two rivers of quite different characteristics.

The single pumping plant on the Delaware was of moderate dimensions, as were two of those upon the Schuylkill, and he urged that the first step toward the filtration of the entire supply should be the construction of a filtration plant or plants in connection with one or two of these smaller stations, said plants to contain installations of each of the systems then best and most favorably known, in order that these might be tested in actual use and in competition with each other, and that the effects of filtration upon the public health might be tested in those limited districts.

It is needless to say that this scheme, like that for the restriction of waste, found no favor with the politicians in charge, and but little, if any, with the benevolent people who were agitating for improvement, and who insisted that the supply for the whole city must be purified at once. Experiment was taboo, for it meant postponement of completion, which, by the way, has not yet been brought about.

We were told that, if a beginning were made with one or two districts, all the others would be up in arms; yet that is exactly what has been done, and no revolution has resulted. We were asked whether filtration had not then "passed beyond the experimental stage."

Among the various schemes then claiming public attention was a large and well-assorted collection of water-snakes, in the shape of benevolent corporations, each with its champions in the city councils, and each kindly proposing to bring the impoverished city out of its water difficulties.

Notable among these was the Schuylkill Valley Water Company, which proposed filtering Schuylkill water, taken below Reading, and which was getting on swimmingly in councils, with every prospect of going through, when an inconsiderate member threw the fat in the fire by announcing that he had been offered a substantial sum for his vote in favor of the company's ordinance.

That such a trifle could block a scheme of this sort shows that the harmony, which has since reigned in the councils of the domi-

nant political party in our midst, had not then been completely established. Nowadays, any reptile cage placed before councils for approval, contains *but one* specimen, and every councilman knows what are his orders from "the front." In those days, however, the administration found itself opposed by an active and powerful faction, which ruled that all improvement of the water supply must await the inauguration of the succeeding administration which they hoped to, and which they eventually did, control.

The result of this policy is seen in the following comparison of estimates for extensions and improvements, and the corresponding appropriations, during the writer's term of service:

	Estimates.	Appropriations.
For 1896..........	$2,484 150	$0
„ 1897..........	3 339 450	0
„ 1898..........	3 735 050	0

Our boilers and engines were strained to the utmost, night and day, and in some cases disabled; there was no opportunity for thorough repairs; we dared not stop pumping during seasons of muddy water; in spite of all manner of pitiful expedients, we were compelled to cut reservoirs off from the distribution and resort to direct pumpage, in order to avoid emptying the reservoirs completely; and from all sides came loud and well-grounded complaints from citizens who paid for a water supply and did not get it.

Nevertheless, as we have seen, the Schuylkill Valley snake came within an ace of getting its appropriation of fifty millions.

During this time the city fathers passed a resolution providing that chiefs of bureaus should devote the whole (only the whole) of their time to the duties of their offices; and the practice of their honorable bodies seemed to be, when they became apprehensive lest the chief of the water bureau might not be earning his salary, to call for plans and estimates for the filtration of the city's supply. These plans and estimates were furnished, to the best of the bureau's abilities, which, at that time, were represented by an engineering force consisting of the chief draftsman and two or three subordinate draftsmen.

One of these requests for enlightenment mentioned "all the water used by the city," and the writer took advantage of the presence of the word "used" to lay before their honorable bodies

comparative estimates of the cost of filtering (1) all the water used, and (2) all the water used *and wasted,* with results as follows:

ESTIMATED COST OF IMPROVEMENT, 1898.

	For Water Used.	For Water Used. and Wasted.
Extensions........	$1 000 000	$5 000 000
Filtration plants ..	2 500 000	7 500 000
Meters............	1 000 000	0
	$4,500 000	$12 500 000

THE PRESENT TRANSFORMATION.

With the advent of the Ashbridge administration, in 1899, the scene shifted. A reassessment of real estate values was made, and the city was said to be in position to borrow practically any sums which might be needed for the improvement of the water supply.

Mayor Ashbridge called in an expert commission, consisting of Messrs. Rudolph Hering, of New York; Samuel M. Gray, of Providence, R. I.; and Joseph M. Wilson, of Philadelphia, who, according to the resolution providing for their appointment, were "to act in conjunction with the chiefs of the Bureaus of Survey and Water."

These gentlemen were, of course, given all needed assistance in their studies, and, after some summer months of hard work, including several all-night sessions by Mr. Hering, their report was published, recommending "the adoption of that project by which the waters of the Schuylkill and Delaware rivers, taken within the city limits, are purified by filtration."

In the body of their report the experts said, "We earnestly recommend the introduction of meters for the city of Philadelphia"; but in their résumé and conclusions the meter was not mentioned, and the deficiency in quantity of supply was ascribed to "the lack of effective pumping machinery and to the insufficient capacity of the distributing system."

The works have cost at least double what would have been required for a lavishly ample supply under proper regulation, and it costs correspondingly to operate them.

Mayor Ashbridge had expressed the wish that the works might

be such as to supply the city for fifty years to come, a view perhaps [illegible] be expected to [illegible] ancestors [illegible] had [illegible] present supply.

[illegible]

phia were those at Lower Roxborough reservoir. In them the water flows vertically upward, first through coke and then through sponge.

The next were those at Belmont for the West Philadelphia supply. In these the water flows first horizontally, through coke passing a 2.5-inch mesh; then horizontally again, through coke, passing a 1-inch mesh; then upward through sponge, and finally downward through coke breeze ranging in size from dust to ⅜ inch.

Both of these plants were designed and built by Mr. P. A. Maignen, and both are working satisfactorily, materially reducing the load on the main filters and permitting a higher rate of filtration through them than would otherwise be compatible with safety.

At Torresdale and at Queen Lane the preliminary filters will consist simply of a series (120 at Torresdale) of rectangular "mechanical" filters, operated without coagulant, and cleansed by reversal of current, and jets of compressed air, as in the filter plants at Little Falls, N. J., and Harrisburg, Penn.

Apart from filtration, the prominent feature of the changes now being made is a reversal of the relation of the Delaware and the Schuylkill as sources of supply, the Delaware being now made the principal source, while the Schuylkill is to be altogether subordinate. Instead of 90 per cent., the new system will take only one third of its supply from the Schuylkill.

For Queen Lane, the experts proposed utilizing the north basin and the larger portion of the south basin for sedimentation, while the remainder of the south basin was to be converted into a clear-water reservoir, and slow filters were to be built upon ground lying just north of the reservoir.

Later, the administration proposed to remove the Queen Lane pumps to the Lardner's Point (Delaware) pumping station and to use the Queen Lane reservoir for the storage of filtered water from Torresdale.

Finally, however, it has been decided to retain the Queen Lane pumping station and to strengthen the foundations of the pumps, to use the entire south basin of the reservoir for sedimentation, and to construct preliminary and slow filters over the north basin, the filtered water to be collected in the lower part of the north

basin immediately under the filters. There will be no pumpage at the reservoir, the water passing by gravity first from the sedimentation basin to the scrubbers, then to the filters, then to the clear water basin, and finally to the distribution. The filters and scrubbers will be supported by concrete columns, piercing the

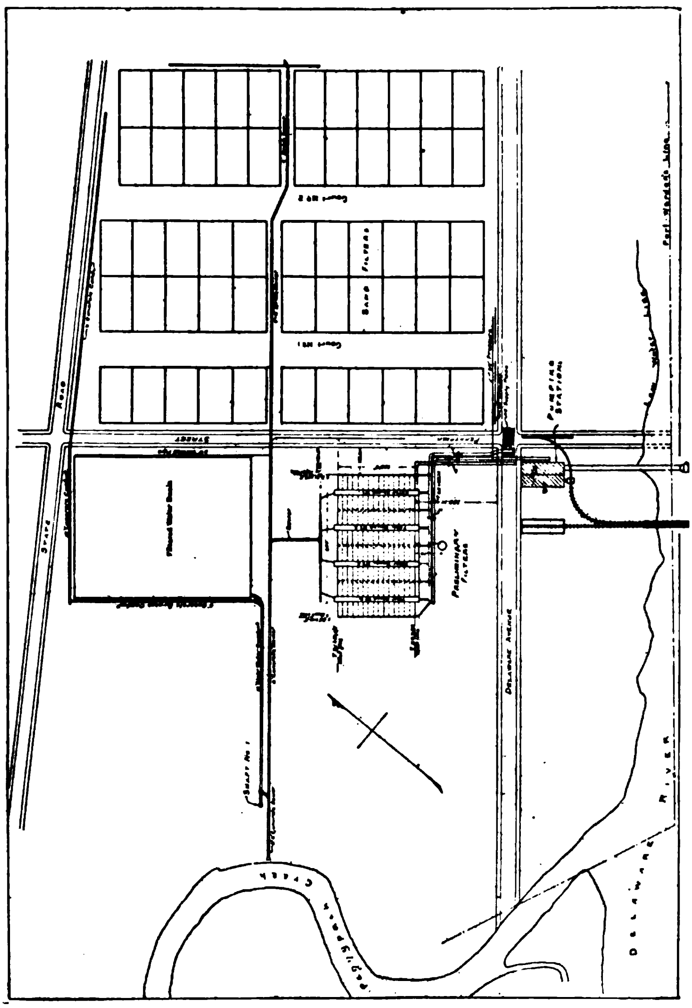


FIG. 5. PLAN OF TORRESDALE FILTER PLANT, SHOWING PUMPING STATION, PRELIMINARY FILTERS, 55 OF THE 65 SLOW FILTERS, FILTERED WATER BASIN, AND BEGINNING OF TORRESDALE CONDUIT.

concrete and clay puddle which form the present floor of the north basin, and resting on rock foundation.

On the Delaware, at Torresdale, two and one-half miles above the former intake at Lardner's Point, a slow filtration plant, believed to be the largest in the world, is now practically completed (see Fig. 5). Here the Delaware water is first lifted by centrifugal pumps to the filters, whence it flows to the adjoining clear water basin, and thence, through the Torresdale conduit, 10 feet 7 inches in diameter and 100 feet below the surface, to the Lardner's Point station, which has been enlarged to many times its old capacity, and which, under the new system, will form by far the largest station for the city's supply, and, it is believed, the largest high-duty pumping station in the world. The new portion of this station will contain twelve new twenty-million gallon pumping engines. When completed, the Torresdale plant will contain 65 filter beds, with a total filtering area of nearly 50 acres, and a preliminary filter plant of 120 rectangular mechanical filter tanks.

Practically, the supply from Lardner's Point will be by direct pumpage of filtered water.

The old Delaware works had but one reservoir, and that a small and defective one, and the great projected Delaware system has also but one small reservoir, and this acts merely to counterbalance the expected inequality between the day and the night demand.

Connected with the Delaware system is one high-service station constructed some ten years ago.

At the risk of advertising an old friend, I will mention that this Wentz Farm high-service station contains one of the few existing d'Auria pumps, another being in operation at the Pleasantville plant which supplies Atlantic City. These pumps are unique in their means for securing high-duty, viz., an oscillating or reciprocating body of water, which acts as a liquid balance-wheel, reversing its direction of motion at each stroke of the pump. The expensive crank and fly wheel are thus dispensed with. The Philadelphia d'Auria was purchased by the Water Bureau in an emergency, and it has since had a checkered career, having been moved about from one station to another and forced to operate generally under unfavorable conditions for which it was not designed. Some years ago it found a resting-place at this little Wentz Farm

station, where it ran for years without a condenser. This lack has been supplied, and Mr. Dunlap tells me that the pump is running well.

It may not be uninteresting to compare Mr. Hill's great Torresdale aqueduct of 1900 with Latrobe's Chestnut Street aqueduct

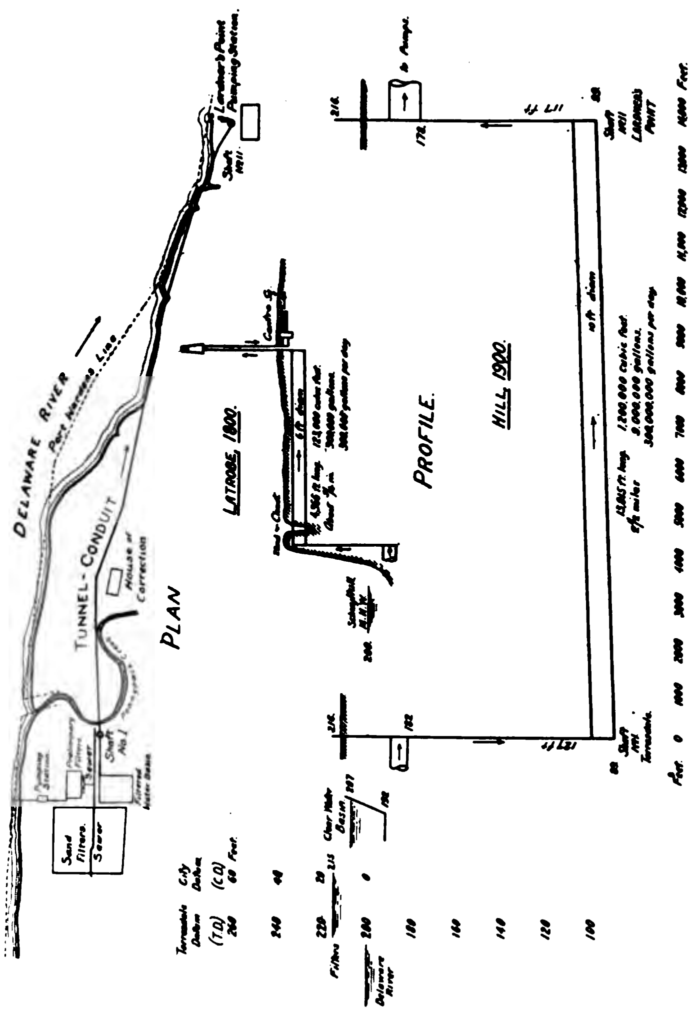


FIG. 6. PLAN AND PROFILE OF TORRESDALE TUNNEL CONDUIT OF 1900, AND PROFILE OF CONDUIT OF 1800.

of 1800. See the accompanying illustration, Fig. 6, which shows both structures at their relative elevations.

	Latrobe.	Hill.
Date	1800	1900
Diameter, feet	6	10
Length, feet	4 366	13 815
Contents, cubic feet	123 000	1 200 000
Capacity, gallons per day	300 000	300 000 000

For convenience of flushing, both aqueducts were given a gentle inclination downward toward their points of beginning. In the Latrobe aqueduct, the flow was by gravity; the slope of the water surface of course producing the flow, notwithstanding the slope of the aqueduct itself in the opposite direction. In Mr. Hill's tunnel, the flow is under pressure, and is caused by the difference in elevation of water surface in the shafts at its two ends.

In 1905 our quiet city was convulsed by a political upheaval. The politicians aroused popular resentment by undertaking a modification of the gas-works lease. Reformers, anxious for improvement, and would-be's, anxious for power and place, seized the opportunity. Mayor Weaver threw in his lot with the new party, threw out his Directors of Safety and of Public Works, and appointed Major Cassius E. Gillette chief of the Bureau of Filtration, to succeed Mr. John W. Hill. Major Gillette, in conjunction with Mr. J. Donald Maclennan, since deceased, reported that, in various ways, the city had been defrauded of some $6 000 000 by the contractors. Thereupon work was stopped for some time, but was afterward resumed, under Major Gillette's charge. With the advent of the present administration, Major Gillette was succeeded by the present chief, Mr. Fred C. Dunlap.

The average daily consumption, during 1907, based largely upon plunger displacement, was 300 000 000 gallons.

The total daily capacity of the works when completed may be stated as 340 000 000 gallons.

The Belmont plant, which supplies all of Philadelphia west of the Schuylkill, has a total nominal capacity of 40 000 000 gallons per day. It has been supplying all, or a part, of this district with filtered water since 1904.

The two Roxborough plants have a combined capacity of 25 000 000 gallons per day. They have been supplying their district with filtered water since 1903.

The Torresdale filter (as yet without scrubbers) in conjunction with the Lardner's Point pumping station (not yet completed) is already supplying the northeastern portion of the city, or say that portion east of Broad Street and north of Spring Garden Street.

The portion of the city not yet supplied with filtered water may be called the central and southern portion, or say the district east of Broad Street and south of Spring Garden Street, and that west of Broad Street and south of Allegheny Avenue.

The works are now filtering from 170 000 000 to 180 000 000 gallons daily. This is about half their intended final capacity and is more than an ample supply for nearly double our present population, but, as we are now wasting at least 100 gallons per capita per day, and using possibly from 50 to 70, I presume that only about one million persons, or about two thirds of our population, are at present supplied with filtered water, while the final supply, of 340 000 000 gallons daily, ample for 5 000 000 people, will be short rations for our one and a half millions.

The important works still to be completed are the preliminary filters at Torresdale, six high-duty pumps at Lardner's Point, and the Queen Lane filters. The preliminary filters at Torresdale are to be completed during the current year, and the Lardner's Point pumps early in 1909, or say ten years after the advent of the Ashbridge administration. The Queen Lane filters have not yet been advertised, and the date of their final completion must depend, to some extent, upon councilmanic appropriations, and these, in turn, of course, upon the grace of his reigning majesty, the Boss.

In round numbers, including engineering and incidental expenses, but exclusive of land damages and experimental and administrative expenses, the changes in the system since 1899, thus far completed or under contract, have cost 26 million dollars, and the work still proposed, but not yet under contract, is estimated to cost 2½ million more, making a total of 28½ million, of which 7 million are being expended upon the Schuylkill and 14½ million

upon the Delaware, 5½ million upon distribution, and 1½ million upon repairs to pumps and stations.

As it will soon be nine years since the writer was officially connected with the Philadelphia water works, he need hardly say that, for most of the information here presented respecting the status and prospects of the works, he is indebted to the present chief of the Bureau of Water, Mr. Fred C. Dunlap, who has extended, to those taking part in this convention, an invitation to visit and inspect the works under his charge.

Any account of the water supply system of Philadelphia would be incomplete without mention of its high-pressure fire service, consisting of a pumping station, at foot of Race Street, Delaware River; four lines of mains, on Race, Arch, Market, and Walnut streets; connecting lines on Second, Fifth, Eighth, and Eleventh streets; and the requisite fire hydrants. Additional connecting lines are now being laid on others of the cross streets. The system extends from the Delaware River to Broad Street. All the mains are of flanged cast-iron pipe.

On Market Street the main is 16 inches in diameter; on Race, Arch, and Walnut streets, 12-inch; and on the cross streets, 8-inch. Chestnut Street was found already so encumbered by underground structures that no attempt was made to lay a fire main there.

The pumping station contains 9 pumps, 7 of 300 horse-power each, and 2 of 150 horse-power each, driven by a gas engine, supplied with gas from the mains of the United Gas Improvement Company.

The maximum fire pressure maintained is 300 pounds per square inch.

The system has been in service for about five years.

AN OLD AQUEDUCT AND ITS DEVELOPMENT.

BY ALBERT L. SAWYER, WATER REGISTRAR, HAVERHILL, MASS.

[*Read September 24, 1908.*]

The water-works system of Haverhill, Mass., is one of the ten oldest in point of organization in the entire area comprised in our Association. There is in our city hardly an institution or business existing to-day that at all approaches it in antiquity of origin, and it is and ever has been most intimately connected with the history and development of the city.

The first municipal water system of which we find record was established at Boston in 1652, consisting of a reservoir about twelve feet square, to which water from springs in the vicinity was conveyed through wooden pipes.

Of the 140 places in Massachusetts having water works in 1890, all but 9 had been built later than 1840, and for the most part since 1870. In the year 1800 there were but 16 places in the United States that had water works, and not one in Canada; and even as late as 1850 there were but 83.

As a matter of record, the sixteen built up to 1800 are enumerated as follows: Boston, 1652; Bethlehem, Penn., 1754; Providence, 1772; Geneva, N. Y., 1787; Salem, 1795; Plymouth, 1796; Hartford, 1797; Portsmouth, Worcester, and Albany, 1798; Peabody, New York City, Morristown, N. J.; Lynchburg, Va., and Winchester, Va., 1799; and Newark, N. J., 1800.

All of these, with the exception of Winchester and Morristown, were built by private companies, but passed into the control of the respective municipalities from time to time up to 1860. The aqueduct at Winchester was built by the municipality; that at Morristown is still owned by a private company.

Of course with a scattered population, where the houses had plenty of surrounding land, wells of pure water were able to amply supply the needs of the people. The denser growth of the towns, the introduction of sanitary plumbing, appendicitis, and the multitude of germs that make life miserable for us to-day, necessitated a corresponding development in the water supply.

It was perfectly natural that the citizens of old Haverhill should have been pioneers, for there are few places that have such an abundance of pure water on all sides, while the situation of the original village, clustered on the waterside, with a natural rise to the three great ponds, offered no problems requiring engineering skill; it was simply to provide an outlet and let the water flow downhill. In fact, we may well suppose that the existence of these natural reservoirs had much influence with the first settlers in the choice of a location for their homes; and certainly there could have been few locations with a more abundant supply of water.

The town of Haverhill, or, as it was originally called, Pentucket, was settled in 1640 by a band of twelve men from Newbury and Ipswich, joined soon after by Rev. John Ward, who became the leader of the settlement, and whose original house is still standing and in the care of the Historical Society. I have a facsimile of the deed from the Indians, Passaqua and Saggahew, in which they made a grant of the lands for the sum of three pounds and ten shillings. As first laid out the town was nearly in the form of a triangle, and included a large portion of the territory now forming the towns of Salem, Atkinson, Hampstead, and Plaistow in New Hampshire, and Methuen in Massachusetts. From the river side the land gradually rises till we come to the large ponds. The nearest, and also the smallest, was Plug Pond, now Lake Saltonstall, and formerly called Ayers Pond from the fact that several people of that name settled near its western end and owned a large part of the adjoining land. This pond has an elevation of 122 feet and covers 70 acres. At the southern extremity was a dam called the "plug dam" in one of the old documents, from which, doubtless, the name of the pond.

Next came Round Pond, with an elevation of 152 feet and containing 80 acres. Round Pond is remarkable from the fact that not a single stream, even of the smallest kind, flows into it, it being supplied, with the exception of the flowage from the surrounding hills, by subterranean springs. Except at one place at the northwest corner, it has a clear, sandy bottom. The natural outlet was toward the southwest into Little River, but the direction of this outlet was long ago artificially changed to secure the surplus water for the mills on the mill brook.

Kenoza Lake, formerly known as Great Pond, was the largest, covering 225 acres, at an elevation of 110 feet, with a large watershed and surrounded by beautifully wooded hills. Its outlet was Fishing River. In 1859 a number of the leading citizens formed a club, purchasing a lot of land on the shore of the lake to be used for picnics and social gatherings.

To John G. Whittier was intrusted the honor of selecting a new name for the pond, and the result was his beautiful poem, " Kenoza," in which he refers to the change of name and to the rare beauty of its natural setting.

> " Lake of the pickerel! let no more
> The echoes answer back ' Great Pond,'
> But sweet Kenoza, from thy shore
> And watching hills beyond.
>
> " Kenoza! o'er no sweeter lake
> Shall morning break or noon cloud sail;
> No fairer form than thine shall take
> The sunset's golden veil."

Crystal Lake, formerly called Creek Pond, was situated about three miles away to the west, and covers 159 acres, with an elevation of 152½ feet. Its shores, quite irregular, are beautiful in spots, the water remarkably clear and transparent, and the bottom for the most part even and sandy. Its outlet is Creek Brook, emptying into the Merrimac.

It was not, however, until about 1799 that any steps were taken to bring the water by gravity to the cluster of houses on the banks of the river, in the fork of the roads formed by the intersection of Main and Water streets. Mr. David How, who at the commencement of the last century was one of the leading citizens of the town, was the first to enter on the project of laying a pipe to bring water from Round Pond to his farmhouse. Iron and even clay pipes were then unknown in this country, and the only method for the conveyance of water was by the use of wooden conductors or bored logs. Mr. How's farmhouse was directly back of that portion of our main thoroughfare now occupied by retail business houses. Here, directly in the center of the town, was his house, and around it were clustered his cow yard and pigpens. There

are some old residents who remember the house as it stood in 1835. Mr. How was still living, but old and infirm. His establishment was then regarded as a nuisance; the dilapidated buildings were reeking with filth, and the stench from his pigpens was an annoyance to all in the little village. To this place Mr. How was desirous of bringing water, and with the assistance of neighbors, green pine logs were bored with a two-inch auger, and a line of pipe was laid to Round Pond.

The idea of an aqueduct appears to have appealed to others of the townspeople, and in 1798 the following petition was presented to the legislature then in session in Boston:

TO THE HONORABLE THE SENATE & HOUSE OF REPRESENTATIVES OF THE COMMONWEALTH OF MASSACHUSETTS IN GENERAL COURT ASSEMBLED.

The petition of Timothy Osgood of Haverhill in the County of Essex & Commonwealth aforesaid in behalf of himself & others Humbly Shews they have in contemplation sinking an aqueduct taking the water at & from the round pond so called in Haverhill & conveying it through the several streets of said Haverhill for the use & convenience of themselves and others who may be desirous of becoming concerned therein & for their greater convenience & security they pray your Honors would grant to them & such others as my associate with them an act of Incorporation Impowering them by the name of Haverhill Aqueduct Company to convey water into the streets in said Town through aqueducts with all such powers rights & privalidges as the subject matter may render necessary & as in Duty bound will ever pray.

TIMOTHY OSGOOD *in behalf of himself & others.*

HAVERHILL Jan^y 8th, 1798.

There were, however, some who did not favor the innovation, for we find in the records of the same year that the town's representative, Mr. Nathaniel Marsh, was instructed " to oppose Osgood's petition for an aqueduct to take water from Round Pond." The petition was evidently granted, however, and in 1801 we find in the town records the steps taken for the formation of the company which from that time on furnished the water supply of the town. This petition was referred to a committee, of which Bailey Bartlett, who for several years was sheriff of the county, was chairman,

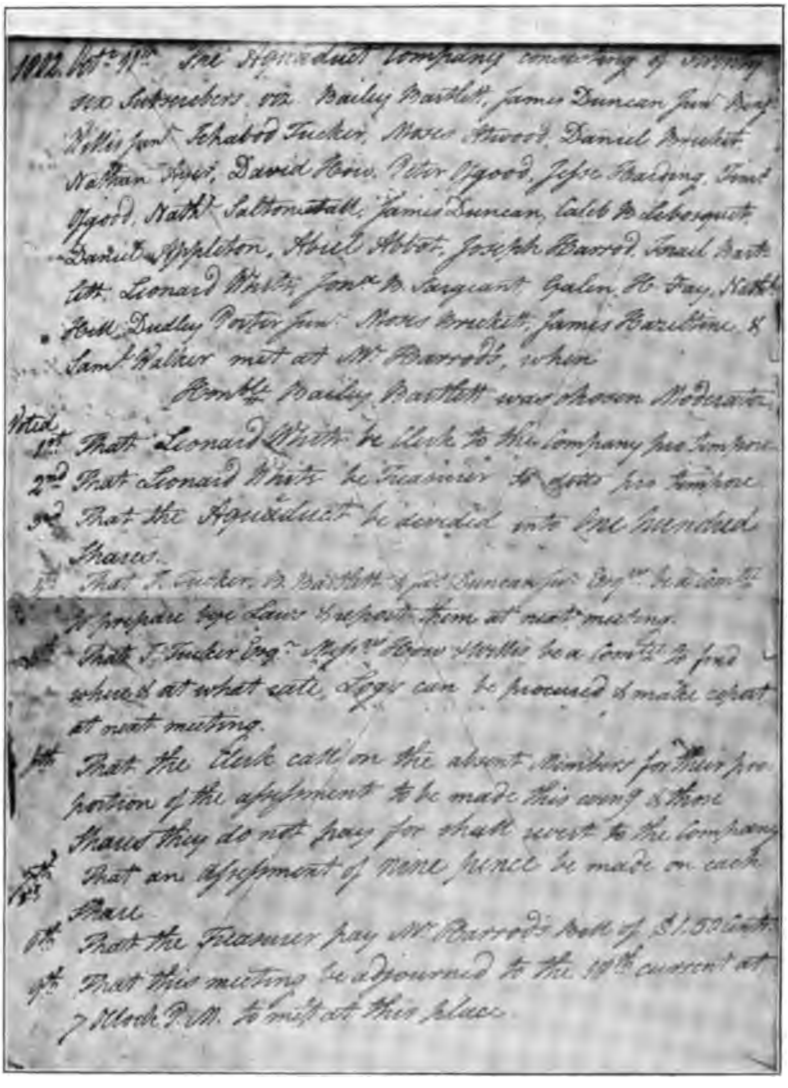
who reported that leave ought to be granted provided that a book for the subscription to the stock was opened to all who chose to take a share; that no one should be allowed to take more than one share until ninety days after the book was opened, at the end of which time the remaining shares might be taken by any of the subscribers; and that the rules of the company be offered to the town for approbation. The following is a copy of the advertisement inviting subscriptions to the stock of the new company.

AQUEDUCT COMPANY.

Notice is hereby given, a subscription
open at the store of Benja. Willis Jun.
for Subscribers to the Aqueduct Company,
which will be kept open for ninety days
agreeable to a vote of the Town, for
any person who may wish to become
a proprietor.
HAVERHILL June 10, 1802.

We might wonder why it was that the first water was taken from Round Pond instead of going to Lake Saltonstall or Plug Pond, which were so much nearer. At that time the outlet of Plug Pond was the mill stream that came down the valley between the old cemetery and the road, entering the Merrimac at the foot of Mill Street, and known as Mill Brook. This brook was about one third of a mile long and had a fall of one hundred and twenty-two feet in that distance, which, with the dam before mentioned, gave ample water power. On this stream was situated the first gristmill of the early settlement. Along the stream at the date of the incorporation of the aqueduct were several manufactories, a tannery, a bark mill, a hat factory, a sawmill, a gristmill, and, at a somewhat later date, a woolen mill; and of course the drawing down of the pond to any great extent would affect the water rights of these mills. In fact, in 1815 a suit was entered against the aqueduct company because they were taking water from Round Pond.

In 1814 Leonard White had conveyed land on the brook and the mill privilege connected with the same to the Haverhill Cotton and Wool Manufactory. A mill was started and cloth manufactured. The next year the company, in the name and with the assent of Leonard White, brought action in which they set forth that by



1802. Octr 11th The Aqueduct Company consisting of twenty six Subscribers viz. Bailey Bartlett, James Duncan Junr Benja Willis junr Ichabod Tucker, Moses Atwood, Daniel Bricket, Nathan Ayer, David How, Peter Osgood, Jesse Harding, Timo Osgood, Nathl Saltonstall, James Duncan, Caleb B. Lebosquet, Daniel Appleton, Abiel Abbot, Joseph Harrod, Israel Bartlett, Leonard White, Jonn B. Sargeant, Galen H. Fay, Nathl Hill, Dudley Porter jun. Moses Brickett, James Hazeltine & Saml Walker met at Mr Harrod's, when

Honble Bailey Bartlett was chosen Moderator.

Voted 1st That Leonard White be Clerk to the Company pro tempore

2nd That Leonard White be Treasurer do pro tempore

3d That the Aqueduct be divided into One hundred Shares.

4th That I. Tucker, B. Bartlett & Jas Duncan jun. Esqrs be a Comtee to prepare bye Laws & report them at next meeting.

5th That I. Tucker Esqr. Messrs How & Willis be a Comtee to find where & at what rate Logs can be procured & make report at next meeting.

6th That the Clerk call on the absent Members for their proportion of the assessment to be made this evening & those Shares they do not pay for shall revert to the Company

7th That an assessment of nine pence be made on each Share

8th That the Treasurer pay Mr Harrod's bill of $1.50 Cents

9th That this meeting be adjourned to the 18th current at 7 O'Clock P.M. to meet at this place.

THE FIRST PAGE OF THE MINUTES OF THE AQUEDUCT COMPANY.

supplying the inhabitants of Haverhill with water from Round Pond the company unlawfully diverted the waters which were a part of Plug Pond and to which the owners of this land and mill privilege were entitled. The manufacturing company was awarded judgment, and from that time until 1849 the aqueduct company used the waters of Round Pond, under an agreement whereby they paid the owners of the land compensation for doing it. Later the company purchased all the land between Plug Pond and the Merrimac River, paying sums ranging from $200 to, in a single instance, $10 000. The Leonard White referred to above was the first treasurer of the aqueduct company, and was placed in the position of bringing suit against his own company on account of having sold the land to the woolen mill.

Having received their charter, the parties interested soon took steps to organize the company, and on October 11, 1802, met at Harrod's Tavern, which stood on the site of our present city hall. I have here the records of that first meeting; this and the records and accounts for many years being in the clear, legible writing of Mr. Leonard White, the clerk, who was, I believe, later the first cashier of the Merrimack National Bank at its incorporation in 1814. (Plate I.)

I ought, as a careful historian, to call your attention to the fact that if they did not at once begin to water the stock, they did at this first meeting mix rum with their water, to the success of the new company, in the good old West India variety, and here is the bill of Landlord Harrod covering the same. (Plate II, Fig. 1.) And I regret to say that this is not all of the sad tale, for as the company got under way their thirst increased in quantity and quality. Let me give you another sample. (Plate II, Fig. 2.)

The managing directors of the company were Hon. Bailey Bartlett, Benjamin Willis, and James Duncan, Jr., and in looking over the records of these early days I have been impressed by the very businesslike way in which all was done. Although the town was small and these men must have seen each other daily, every order to the treasurer for the payment of money is in the writing of the directors; and Mr. Harrod, who was one of the incorporators, never forgot to put in his bill for liquor consumed. When James Duncan went to Boston and brought out the iron for binding the logs, we

find his bill for thirty-five cents, and there is a bill from Bailey Bartlett of thirteen cents for a paper book and other items, concluding with a charge of forty dollars for overseeing the laying of the logs. They all appear to have cheerfully paid out of one pocket assessment after assessment on their stock, and then as cheerfully got the most of it back into the other pocket in the shape of bills and sundry small dividends declared from time to time.

We have heard considerable at some of our meetings about specifications for iron pipe, and you may some of you like to hear the original contract and specification for pipe made in 1803:

Articles of Contract and agreement made this 26th. day of Jan. 1803 Between Bailey Bartlett, Benj. A. Willis and James Duncan Jr. in behalf of Haverhill Aqueduct company on the one part and Enoch Noys of Barr in New Hampshire on the other part witnesseth

The said Enoch Noys for the consideration hereafter expressed does hereby contract and engage to deliver at some landing near Haverhill Bridge on or before the 20th day of May next, eight thousand feet in length of good sound white or yellow pine timber of the following dimentions; no stick to be less than fifteen feet in length; one third of the quantity to measure at the top end nine inches; one third ten inches, and one third twelve inches, the same to be straight and sound and said measure is to include the heart only.

And the said Bartlett, Willis and Duncan in behalf of said proprietors do hereby engage to pay said Noys at the rate of twenty shillings for each and every ton the same shall measure, reconing the same as measured at the top end and free from sap and of the three several dimentions as above stated, the same to be paid on delivery of the whole timber.

BAILEY BARTLETT
BENJ. WILLIS
ENOCH NOYES

Signed in the presence of
ROBERT McGREGOR

CONTRACTS TO BE MADE FOR THE AQUEDUCT COMPANY IN HAVERHILL.

1803

May 3. First for Digging the Ditch to lay the Logs from a Stake & Stones near the Pond Brook to a Stake & Stones

No. 1 by Sam Walkers land about 150 Rods — the ditch to be not less than 3½ feet Deep and wide enough to lay the logs, the bottom of the Ditch to be level, sufficient for the logs to lay fair on the same.

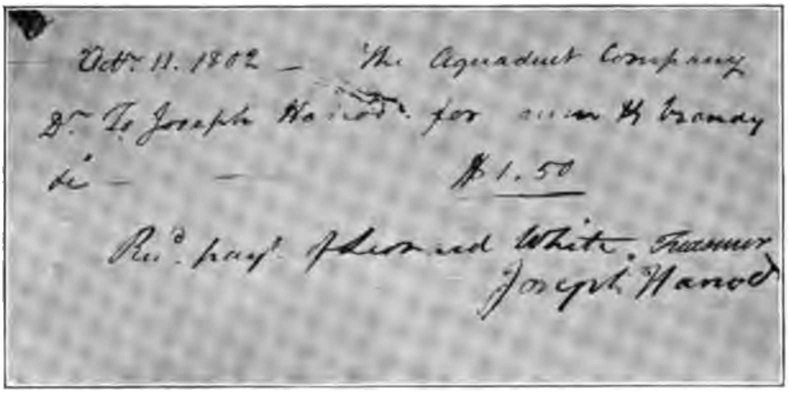

Octr. 11. 1802 — The Aqueduct Company
Dr. To Joseph Harrod for [illegible] brandy
&c — — $1.50
Recd. payt. of Leonard White, Treasurer
Joseph Harrod

FIG. 1. FIRST BILL PAID BY THE AQUEDUCT COMPANY.

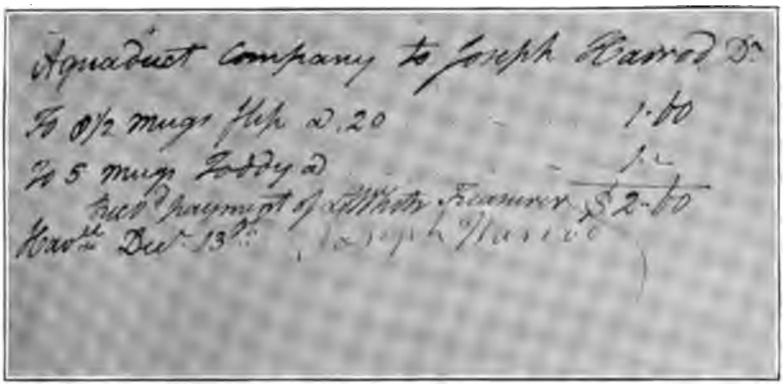

Aqueduct Company to Joseph Harrod Dr.
To 8½ mugs flip @ .20 — 1.60
To 5 mugs Toddy @ — 1.00
Recd. payment of L. White Treasurer $2.60
Havd. Decr. 13th (Joseph Harrod

FIG. 2. ANOTHER EARLY BILL.

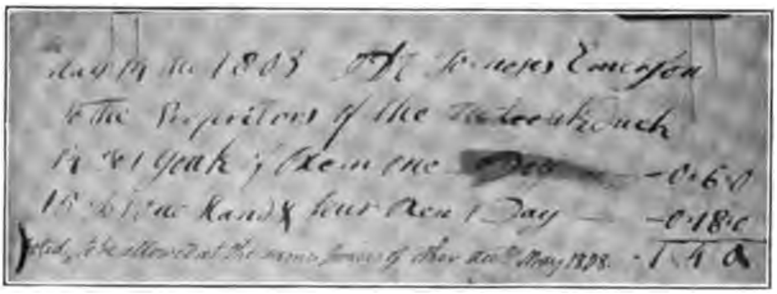

May 19 the 1808 [illegible] Moses Emerson
to the Proprietors of the [illegible]
[illegible] —0.60
[illegible] Day —0.18
[illegible] May 1808. 1.4 [illegible]

FIG. 3. BILL FOR HAULING LOGS.

No. 2 Contract — beginning at the lower End of N°. 1 — and continue to Caleb Bosquets House opposite the Front Door.

No. 3 From the above mentioned Door to Hav'll Bridge.

N. B. In case, the Contractors in digging any part of the ditch abovementioned, should come across any Rocks of more than ten hundred Weight or Fast ledge of Rocks they shall have liberty to dig round the same, or to remove the rocks at the direction of the Directors, in which case the Directors will pay the extra expense. Where it is necessary to take down any walls in the prosecution of the work, they shall be put up by the directors at the expense of the aqueduct Company.

No. 4 Contract for covering the Logs when laid; the whole dirt taken out, to be thrown upon the Logs as fast as they are laid, and ready for covering. From the Pond to the Bridge the same to be by the Rod.

No. 5 Boring Fixing & laying the logs Fit for Covering, the Proprietors to find the Iron Hoops to put on the ends of the logs. 4000 feet of Logs with a two Inch Augur
4000 feet Do 1½ Inch bore — to be well rimmed out. the whole to be done in a workman like Manner and to the approbation of the directors and to Include the logs to extend from the main logs to the Houses

The contractor evidently had good luck, for here is the bill of Moses Emerson, dated May 14, 1803 (Plate II, Fig. 3), against what he terms the "Accuduck" for the use of oxen in hauling the logs from the landing. But I must stop no longer with these interesting relics of the past.

Returning again to the log aqueduct, let me refer to some of the early trials and tribulations that even to the present day are connected with water-works administration. After the water had been let on, the pressure was so great that the log pipes, unable to stand the strain, burst. This was a grave difficulty, and all the hydraulic skill of the times was brought to bear on the problem. At last the idea was hit upon of making a break in the pipes half way down the hill, by digging a pit, and thus relieving the pressure. This pit was placed nearly opposite the Unitarian Church and remained there for nearly forty years.

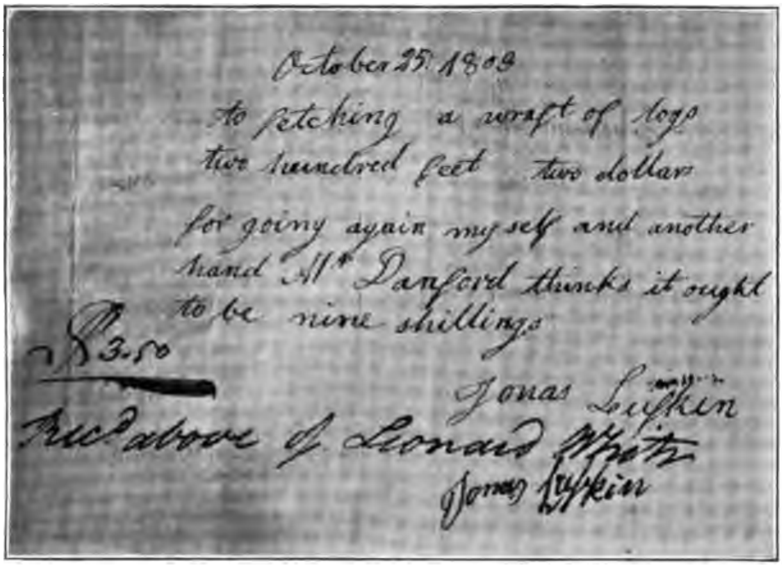
In the early stages of the company no water was carried above

the first story of the houses, and no lead or metal stop cocks were in use. The logs were brought directly into the kitchens and cow yards, and an upright bored log with wooden faucet held the water for use. A curious device was used on Main Street, near the North Church, to elevate the flowing water so as to bring it into the kitchens of the houses. It was found that the water would flow through the logs all right, but it would not stop to be taken on the way; and to remedy this evil, an upright log was interposed and bored double, so that the water was forced to ascend one tube to the top and flow over for its passage down town. This held the water back so that customers on the level street could get a supply. This was considered a great piece of engineering skill, and some elderly citizens might doubtless recall how as boys they jumped on the log and listened to the murmur of the water as it flowed over.

It has been said that various evils result from indulgence in strong drink, and in the case of the aqueduct company it took the form of — betting! The hydraulics of the working plant of the company caused differences of opinion as to pressure, etc., and at last, doubtless after a business meeting held by the open fire at the hospitable Harrod's, the discussion grew heated, there was a division among them, and the following bet was made:

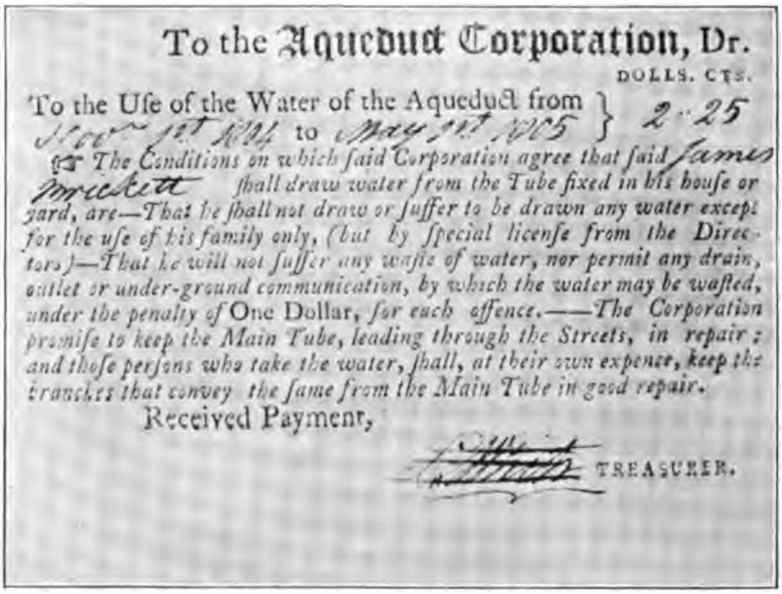
> The bet is in the form following, viz.: a barrel being filled with water and set on the ground a tube of ½ inch bore & 40 feet long inserted into the barrel & made tight, and filled with water and a funnel on the top of the tube filled also with water, the barrel will burst.

Burst.	Will not Burst.
B. Bartlett	J. Duncan
D. How	B. Willis, Jr.
L. White	M. Atwood
O. Tucker	P. Osgood
M. Brickett	B. Willis
C. Kimball	N. Ayer
J. Harrod	D. Brickett
T. Jordan	D. Portor Jun.
T. Brickett	H. West
N. Marsh	
E. Hale	



October 25 1809
to fetching a wraft of logs
two hundred feet two dollars
for going again myself and another
hand Mr Danford thinks it ought
to be nine shillings
$3.50
Jonas Lufkin
Recd above of Leonard White
Jonas Lufkin

FIG. 1. BILL FOR RAFTING LOGS FOR PIPE.



To the Aqueduct Corporation, Dr.

DOLLS. CTS.

To the Uſe of the Water of the Aqueduct from Nov 1st 1804 to May 1st 1805 } 2 . 25

☞ The Conditions on which ſaid Corporation agree that ſaid James Mrickett ſhall draw water from the Tube fixed in his houſe or yard, are—That he ſhall not draw or ſuffer to be drawn any water except for the uſe of his family only, (but by ſpecial licenſe from the Directors)—That he will not ſuffer any waſte of water, nor permit any drain, outlet or under-ground communication, by which the water may be waſted, under the penalty of One Dollar, for each offence.——The Corporation promiſe to keep the Main Tube, leading through the Streets, in repair; and thoſe perſons who take the water, ſhall, at their own expence, keep the branches that convey the ſame from the Main Tube in good repair.

Received Payment,

TREASURER.

FIG. 2. AN EARLY BILL FOR WATER RATES.

As the town grew, the two-inch logs were found insufficient to supply water, and about 1830 four-inch logs were substituted, and the aqueduct was extended to some of the streets intersecting with Main Street. The price at first charged was $4.50 for houses and beasts, providing subscription for taking the water was made before the logs were laid, otherwise it was to be $5, and an additional charge was made for each additional post. There appears to have been no printed rate sheet until 1822. In making this the proprietors evidently took as a basis the rules and rates of the Salem and Danvers aqueduct as established in 1797, which I have altered in several places, and marked " adopted by the Haverhill Company." The rules as finally adopted and printed were as follows:

RULES AND REGULATIONS of the
HAVERHILL AQUEDUCT COMPANY, AS AGREED
ON BY THE PROPRIETORS, JUNE 14, 1822.

Article 1. — The Proprietors engage to support the expence of maintaining the main tube from the Pond, and ten feet offset from the same, measuring from the centre of the street; the remainder of the branch and vent-stock shall be made and supported by the person who takes the water, under the care and direction of the Agent of the proprietors, or of one of the directors.

Article 2. — The Annual sum to be paid for the use of the water from said Aqueduct, shall be as follows . . . viz.
For all families less than nine persons in a family, Eight Dollars.
For all private families of nine persons, or more, Nine Dollars.
For a Tavern or public Boarding house, Eleven Dollars.
And if for a House and Stable, Fifteen Dollars.
One half to be paid to the Treasurer in Six months, and the remainder in Twelve months from the time of taking the water.

Article 3. — The Annual sum to be paid by Distilleries, Manufactories, or other persons not included in the above, shall be such a sum, and under such regulations as may be agreed on with the Directors, to be paid in the times above specified.

Article 4. — No person taking the water from said Aqueduct, shall suffer a waste of water, or permit any person other than his own family to take the same.

Article 5. — Every person having a branch shall be subject to have the drawing place therefrom, and everything appertaining thereto, inspected at the direction of the Agent, or one of the Directors, whose duty it shall be to superintend the works generally.

Article 6. — Should there be a deficiency of water, on notice thereof being given to the Agent or one of the Directors, the pay for such time shall cease, if occasioned by a want of water in the main tube; but the proprietors will in no case be responsible for defects in the offsets or ventstocks, arising from frost or other causes.

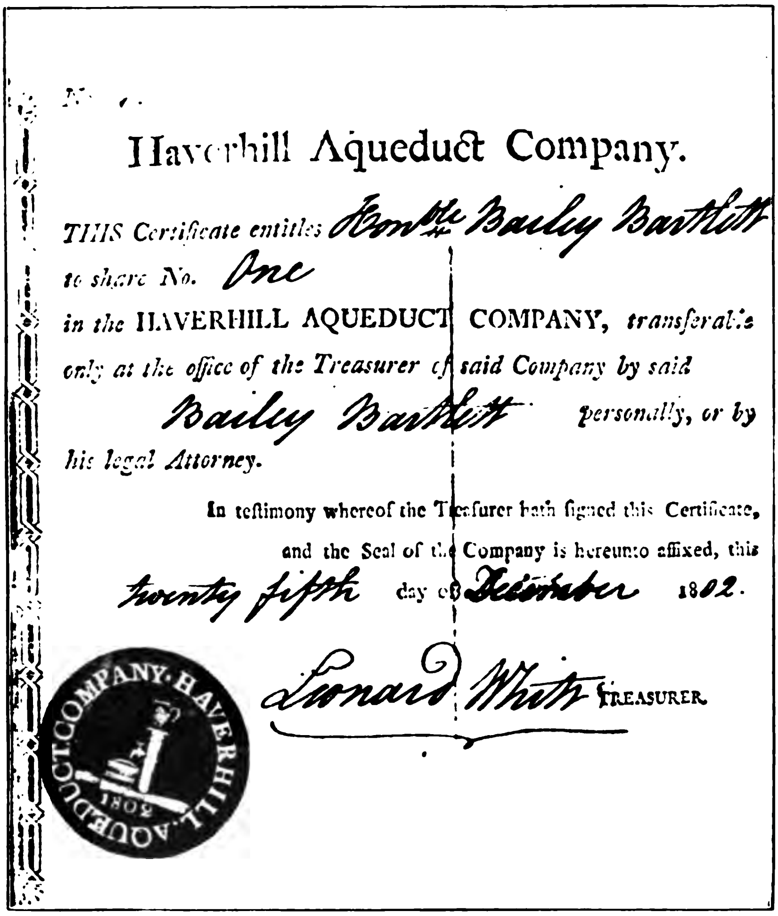
Article 7. — In order to prevent freezing, all persons taking water for family use will have liberty (at their own expence) to take it into their cellars, as well as above stairs.

Article 8. — Each person taking the water from said company, shall be furnished with a printed copy of these rules subscribed by the Clerk, and shall also subscribe a like copy to be kept by the Clerk of said company, stating that they will conform to these regulations and also stating the number of persons in his family and the use he expects to make of the water.

CHARLES WHITE, Clerk to Props.

The prices for water varied somewhat until 1845, when a uniform tariff was made for ordinary family use, and the rates were not materially changed thereafter until the works were taken over by the city.

An old man by the name of Jordan had sole charge of the works, and the boys were in the habit of calling the aqueduct the "River Jordan." He bored the logs, put them down, attached faucets, made repairs, thawed out the stream when it was frozen, made out the bills, and collected the money as well as he could. He was the one who "ran the machine." His services were in constant demand, especially on frosty mornings, and old boys have told the story of being called out in the cold gray of the morning to hunt up "old Jordan" to thaw out the frozen logs. His house was at



No.

Haverhill Aqueduct Company.

THIS Certificate entitles Hon^ble Bailey Bartlett *to share No.* One *in the* HAVERHILL AQUEDUCT COMPANY, *transferable only at the office of the Treasurer of said Company by said* Bailey Bartlett *personally, or by his legal Attorney.*

In testimony whereof the Treasurer hath signed this Certificate, and the Seal of the Company is hereunto affixed, this twenty fifth day of December 1802.

Leonard White TREASURER.

FIRST STOCK CERTIFICATE ISSUED BY HAVERHILL AQUEDUCT COMPANY.

the corner of Main and Pond streets, and an elderly gentleman told me within a year that he well remembered the piles of logs stored by the roadside, and watching the boring process carried on. I have two samples of the log aqueduct (Plate V). This large section is undoubtedly a piece of one of the very early logs laid, as it was dug up at the corner of Main and Water streets. The other section is of a much later vintage, being dug up on Kenoza Avenue. You will note the marks where it was strengthened by hoops of iron.

About 1840 the old aqueduct was found to be inadequate to supply water, and Charles Minot, Esq., a well-known lawyer, took it in hand, raised money, and extended the pipes. The number of shares was one hundred and the par value, I believe, was $25. With the funds obtained he laid some iron pipe and put the works in better repair. After a few years Mr. Minot was called to act as superintendent of the Boston & Maine Railroad and the aqueduct was purchased to a large extent by Hazen Haseltine, an active business man of the times. His business career was, however, terminated by a failure, and among his assets was a majority of the stock of the company, which passed into the hands of his brother, Ward B. Haseltine, of Philadelphia, who took it, much against his inclination, as security for money loaned to his brother.

Soon after 1845 it was found that more water was needed, and Plug Pond was tapped. Quite a controversy took place at this time over the so-called encroachment of a soulless corporation in planning to take water from this pond, and so destroy forever the beauty and utility of the old mill brook. The culminating point was perhaps reached in the following communication, published in the *Tri-Weekly* by one who signed himself "Mill Street":

"More beautiful to my youthful eyes were the buttercups and thistles which grew on the borders of this much-talked-of brook than the rarest exotics in the parterres of the wealthy and great. The fairy-like music of its crystal waters, as they roared and rippled and seethed and surged and tumbled over its stony bed, was ever suggestive of elves and water-nymphs.

'I envied the brook as it glided along,
Thro' its beautiful banks in a trance of song.'

But there is one point your correspondent has failed to notice,

which would, 'I apprehend,' be more regretted by lovers of art than words could express. I refer to the sweet and pathetic music of the frogs. Have you ever, Messrs. Editors, on a calm, moonlight midsummer's eve, seated yourself on the grassy bank of the upper Mill Pond and drank in the beauty and inspiration of the scene? the majestic rock-ribbed hills in the distance, the stately poplars, the regal sycamores, and the graceful elm reflecting every limb, and twig, and leaf, in the glassy mirror below; the whole scene, so tranquil and soothing, undisturbed by any earth-born sound, save the dulcet melodies of the frogs. The deep diapason of the masculines, the soft, tender responses of the lady frogs, the sweet baby trills of the pollywogs, and the blending of the three in one harmonious whole, produce such a 'concord of sweet sounds' as to make one feel in his heart of hearts the sentiments of the immortal poet, 'linked sweetness long drawn out.'

"I, in company with appreciative friends, have often listened in charmed ecstacy, and the memory of such evenings is 'a joy forever.' And are we, and our children, and our children's children, to be deprived of this exquisite source of enjoyment, so refining and exalting in its nature, for the accommodation of a 'few individuals' who, under the pretence of 'supplying the town with pure water,' are committing acts of vandalism on Mill Street that *no* necessity ought to justify?

"MILL STREET."

Again, in 1867, the two sources of supply proved inadequate, and the owners went to the legislature for permission to draw water from Kenoza Lake. An act was passed, with certain restrictions:

1. Private property was safeguarded by preventing the raising of the ponds *above* high-water mark or lowering them below low-water mark.

2. The water of none of the ponds could be used to drive machinery.

3. A plan was provided by which the city could take over the works.

In 1848, at the town meeting, a proposition was made for the town to pay the difference between a 5-inch and 8-inch iron pipe from Round Pond to the top of the hill on Main Street, the Aqueduct Company being about to replace the old logs with a 5-inch pipe of iron. A committee to whom it was referred reported in favor of a 6-inch pipe, which was laid, the town paying the difference in cost. Soon after this Mr. James H. Carleton obtained

PLATE V.

FIG. 1. PIECE OF LOG PIPE.

FIG. 2. SECTION OF LOG PIPE.

control of a number of shares held by various local people. For more than forty years the stock was owned by the two previously-named gentlemen, the rest being divided up among five prominent citizens. Mr. Carleton was for many years treasurer and superintendent, being succeeded later as superintendent by Mr. Charles W. Morse, who continued until the city took possession in 1891.

In 1871 a small pump was erected at Kenoza Lake and water was pumped into Round Pond, the system still being gravity. In 1879 the growth of the city had extended greatly and buildings were being erected on the high lands of the city, and the company then added what is now known as the old pumping station, erected a standpipe on Kenoza Avenue, and began to supplement the gravity system by a high-service system. At the same time there was in the western part of the city a reservoir on Silver Hill, or Mt. Washington. This was supplied from springs and was the property of the Silver Hill Aqueduct Company, and was used for the purpose of supplying a little settlement of houses in that vicinity. The Haverhill Aqueduct Company at this same date acquired by purchase and deed this property.

In 1882 it became apparent that there was a permanence in the growth of the city which would require a greater supply than they were then enjoying, and the same year they went up to Crystal Lake and acquired the mill sites on the stream flowing from the lake. In 1884 the legislature granted them the right to use the water of Crystal Lake as a source of supply, and the company immediately laid its line of 16-inch cement pipe from Crystal Lake into the city. In 1889 the growth of the city on the high lands of Mt. Washington had continued and it was again necessary that the high-service system should be supplemented. Another standpipe was erected on a tract of land acquired for the purpose on Grove Street.

In 1884, owing to the dissatisfaction of some of the large water takers with rates, an agitation was made looking to the purchase of the plant by the city, under the Act of 1867; hearings were held by a committee of the city government, but nothing was at this time done. In 1890, however, another committee was appointed, with an appropriation of $500, to investigate and report on the advisability of acquiring the property and franchises of the Aqueduct

Company. After an exhaustive hearing, the formal order of taking was passed by both branches of the city government, and the order was approved by Mayor Burnham July 10, 1891. By this order the mayor was directed to apply to the Supreme Judicial Court for the appointment of three commissionars who were to determine the price of the franchise, rights, and property of the company. The Court appointed Hon. George O. Shattuck, John E. Sandford, and Weston Lewis as commissioners. They held their opening session May 14, 1892, and on the 17th day of October, 1892, the commissioners reported that the price to be paid by the city was $637 500, with interest from the 6th day of July, 1891; the city was also to pay the fees of the commissioners, which were fixed at $7 655.

The Aqueduct Company was represented by Hon. William Gaston, E. T. Burley, Esq., Boyd B. Jones, Esq., and Frederick E. Snow, Esq.

The counsel for the city were Hon. George D. Robinson, Hon. William H. Moody, and Edward B. George, Esq.

The total cost to the city of the hearings, including experts and counsel fees, was about $22 000.

The authority under which the works were taken by the city and have since been conducted was an act of the legislature, passed in 1891, and two supplementary acts passed in 1892 and 1896. These acts were drawn by Hon. William H. Moody, now one of the justices of the United States Supreme Court, who at that time was chief counsel for the city, and on the formal taking of the works was appointed one of the water commissioners. The original act was different from other acts regarding water supply in several particulars. Mr. Moody writes me that "the main purpose which I sought to accomplish, carrying out in this respect the wishes of the mayor and city council then in office, was to separate completely the water department from all other affairs of the city. It was hoped thus that the department would be managed upon strictly business principles without regard to politics. To that end it was provided that the water commissioners should be appointed for a term of five years, that only one should be appointed each year, and that the city be left to pay for the water which it used like any other consumer. The power of management of the

department was vested exclusively in the commissioners, subject to removal by the city council for cause." Mr. Moody further writes that "in the Act of 1892, which referred to the taking of lands for the protection of the water supply, I put into it the provision that any land taken for the protection of the water supply might be managed, improved, and controlled by the water commissioners in such manner as they should deem for the best interests of said city. The purpose of this provision was to enable the land thus taken to be used for the purpose of a public park, as it has since been. I hoped for good results, but I didn't realize that the result would be a most beautiful park in which all our people may justly delight."

Under this act the water board has taken 623 acres of land, at a cost of $157 432, the larger portion of this being about the storage basin and Kenoza Lake. A portion of this is placed under the control of the park department at the discretion of the water board.

For five years the city paid for the water used in all public buildings and drinking fountains. Then came the same trouble that so many water works have had to meet, — a city council short of money, — and the question was raised why, as the city owned the works, any rates should be paid. The matter dragged along for several years, but no adjustment was ever made, and the city has since then not paid a penny for water. In our case it has seemed particularly unjust, since not a dollar has ever been paid by the city towards buying the plant, operating it, or toward the sinking fund. We charge the owners the entire cost of putting in the service, and the city pays all bills of this kind for the different departments of the city.

Early in 1882 Haverhill was visited by a disastrous fire that reduced almost the entire "shoe district" to ruins. The next year the city council appointed a committee on water supply, authorized "to cause to be laid by contract or otherwise cast-iron pipe 12-inch in diameter, to be connected at the North Church with the high-service pipe of the Haverhill Aqueduct Company." This pipe was to be used exclusively for fire service, and was laid through the main streets of the city, taking in the retail section and that portion occupied by shoe factories. An appropriation of

$30 000 was made covering the cost, and the work was done under the direction of the committee. As the manufacturing district has expanded, calls have been made for extension of the high service in various parts of the city, to be used exclusively for fire protection, and appropriations have been made by the city council, the water department doing the work.

The hydrants are all under the control of, and are furnished by, the fire department, but are set by our department and the expense paid by the city.

The water commissioners have the right to fix the water rates; the income, after deducting all expenses and charges of distribution, is applied, first, to the payment of the interest on the bonds; second, to the payment of the sinking fund requirements (two per cent. of the total amount of the bonds); third, to the payment of all current expenses; fourth, the balance, if any, may be applied to the sinking funds in the discretion of the commissioners. We are also allowed to expend not exceeding twenty thousand dollars in any one year for the purpose of new construction. In case the surplus should not equal the two per cent. required for the provision of the sinking fund, the city must raise such sum by general taxation.

Our department receives all money from rates, etc., and pays its own bills, the only connection with the city being the appointment of a commissioner each year by the mayor, the auditing of the books of the department by the city auditor, and the payments for interest and sinking fund, which are made to the city treasurer. The result aimed at has been achieved, the department having been so far kept entirely out of politics.

None of the commissioners, with the exception of the chairman, receives pay, and up to the present the members of the board have all been leading citizens who have freely given of their time, and have been reappointed as long as they desired to remain upon the board.

The improvement and development of the system since its acquisition by the city have been on the lines laid down by the consulting engineer, the late Freeman C. Coffin, who in January, 1895, submitted an exhaustive report on the needs of the plant, and the sources of additional supply; and the result is a system

fully equipped and capable of supplying an abundance of pure water, at a cost to the consumer comparing favorably with other cities of the country. At the present time, a large section of the city is supplied by gravity from Crystal Lake, Round Pond, and Lake Saltonstall. Kenoza Lake supplies those portions of the city that are dependent on high service, and also furnishes water for the fire service, the water being pumped to a reservoir of 9 000 000 gallons capacity, built in 1898. As an auxiliary supply we have Millvale storage basin, which was built in 1894–5 by damming East Meadow River, and which has a capacity of 118 000 000 gallons. A Worthington engine with a capacity of 8 000 000 gallons per day is installed at Millvale, and the water is pumped through a 24-inch pipe into Kenoza Lake, a distance of one mile, as required to keep that lake at a proper height. A 16-inch pipe connects Kenoza Lake and Round Pond. At the new Kenoza station, erected in 1900, are two pumps, one made by the Barr Company, of Philadelphia, with a capacity of 6 000 000 gallons; another of like capacity made by the Platt Iron Works Company, of Dayton, Ohio.

In 1896 the town of Bradford, situated on the south bank of the Merrimac River, was annexed to Haverhill, and the Water Board took in charge the water system of that town, which had been installed by Messrs. Goodhue & Birnie, of Springfield, as a private enterprise, and later taken by the town. The water for this portion of the city is furnished from Johnson's Pond, with an area of twenty-two acres, and is all high-service, pumped to a reservoir of 1 000 000 gallons capacity by a two-million-gallon Deane pump. The water board is about to install a second pump at the plant, and eventually will probably lay a pipe across the river, which would be of use to either section in case of emergency.

We supply an estimated population of 37 600, our consumption being 134 gallons per day to each consumer. This high consumption is due to the fact that outside of the business portion of the city the use of meters has been optional, and at the present time we have in use only eight hundred meters. We have eighty-four miles of main pipe, cement lined and cast iron, ranging in size from two to twenty-four inch. The pressure on the low service ranges

from thirty-five to forty pounds, while the high service is from eighty to one hundred and twenty. The original cost of the works in 1891 was $720 504.17. The cost of the works December 1, 1907, which, of course, includes all the improvements above mentioned and the land purchased, was $1 466 594.51, while the net debt at that same date was $646 491.

And in addition, what is after all of the most importance to the water takers of the city, is the fact that since 1892 the rates have been year by year decreased. After several reductions in the tariff of rates, the commissioners adopted the policy of a discount of 5 per cent. for prompt payment of bills, and this has been increased to 10, 15, 20, and 25 per cent.

Like many another of the old landmarks, the log aqueduct long since passed away, and except perhaps as a matter of history, is no longer interesting. But the main fact remains, that we have to-day an institution that has survived since 1802 and has developed to its present condition. Started by some of the leading men of the time, identified with the growth of the old town, it certainly was not altogether for what there was in it. For years its earnings were small and less than the expenses, and even after its reorganization, for a long period no dividends were paid, and assessments on the stock were made. And not only that, but the task was a thankless one. The community viewed the venture as chimerical, and the individuals engaged in it as foolhardy in the extreme. The town scoffed at the idea, and the multitude believed that there was not then nor ever would be any use for such a contrivance as an aqueduct.

Who can say to-day how much the existence of the facilities for water afforded through the past history of the town and city, and due largely to the enterprise of these townsmen, has contributed to its progress and present prosperity?

DISCUSSION.

MR. M. N. BAKER. Mr. President, I think we are all agreed that this is a unique contribution to the history of American water works, and that the author of the paper is to be thanked for having taken so much pains to bring together such a large amount of valuable historical matter. It would be a very fine thing if others

in position to do so would follow his example and put on record the history, in so far as it has not yet been done, of at least those water works that were built up to the early part of the nineteenth century. The number of works, as has been stated in the paper, in operation up to the close of 1800 is small. Even well into the nineteenth century, there were only thirty-two works. I hope that it will be feasible to reproduce in the JOURNAL some of these very interesting historical documents which Mr. Sawyer has shown us. I am sure they would be of great interest to all the members of the Association, and of value to others outside of the Association who may wish to refer to the JOURNAL in the years to come for just such matter as this. Those of us who have attempted to make similar investigations know how difficult it is to bring together material of this sort, and I think it is very rare indeed to find such complete records, covering a period so long past.

BULLETIN OF THE HOQUIAM WATER COMPANY, HOQUIAM, WASH.*

BY HARRY C. HEERMANS, PRESIDENT.

CHEAP TRANSPORTATION AND DELIVERY OF PUBLIC WATER SUPPLY.

Examine the tables in this bulletin. They will agreeably surprise you. Please remember in paying your water bill that you pay for the collection, pumping, and delivery of an adequate water supply, *when* you want it, *where* you want it, and in quantity to supply your requirements. No worry. Your rate is based on the quantity required for the uses you specify in your application to the water company. You do not pay for wastage and you are, therefore, requested to treat the company fairly and prevent waste. That is the only square deal. Think of the luxury and cheapness of a public water supply. You make no investment for wells, or cisterns, or storage tanks; no labor at home pumping water or cleaning cisterns, wells, or tanks, and no payment of constant repairs to the same. The public supply furnishes your home with hot or cold water everywhere if you want it and is the cheapest commodity you buy.

Think of these facts and *smile* when you pay your bill to the water company.

COST OF WATER, DELIVERED BY WEIGHT, ACCORDING TO VARIOUS RATES, THROUGH WATER-WORKS SYSTEMS.

Attention is called to the fact that the delivery of water by weight, through public water supply systems, as a commodity, is the cheapest in the known world, in comparison with other transportation; for instance, the switching of a car containing fifteen tons of freight, switched within the city limits by any railroad company, would not be less than $2.00, or 12⅔ cts. per ton.

Last summer the Hoquiam Water Company paid for the switch-

* This bulletin is reproduced for the benefit of water-works managers generally.—EDITOR.

ing and transportation of carloads of water pipe, a distance of not over two or three miles, the sum of $15.75 per car, or .877 cts. per ton (wire banded wood pipe).

We are now collecting the Hoquiam water supply at the average distance of five miles from town, pumping and delivering the same to consumers in their homes at any elevation required, not exceeding 200 feet above sea level, at the rates per ton as shown in the following table:

Prices per 1 000 gallons delivered through water-works systems..............	$0.08	.15	.20	.30	.45	.50
Prices of water per ton, delivered by various water companies............	$0.019	.036	.048	.072	.107	.119

One thousand gallons of water weighs 4.175 tons.
One gallon of water weighs 8.35 pounds.
One cubic foot of water weighs 62.42 pounds. — (Trautwine.)
One cubic foot of water contains 7½ gallons.

THE REASON WHY WATER TAKERS SHOULD PREVENT LEAKS IN PLUMBING FIXTURES.

[Data taken from book on hydraulics, by Geo. A. Ellis, C. E.]

Amount of water, in gallons, that will pass through pipes or jets of various sizes in one hour under different pressures of the Hoquiam Water Company:

Size of Openings.	85 Pounds Pressure.	90 Pounds Pressure.	95 Pounds Pressure.	100 Pounds Pressure.
1-16 inch.......	64.2	66	67.8	69.6
1-8 "	258.6	265.8	273	280.2
3-16 "	577.2	593.4	612	624
1-4 "	1 032	1 062	1 090	1 122
3-8 "	2 310	2 376	2 442	2 502
1-2 "	4 128	4 248	4 368	4 476
5-8 "	6 420	6 600	6 780	6 960
3-4 "	9 300	9 600	9 880	10 080
7-8 "	12 600	13 020	13 380	13 680
1 "	16 500	16 980	17 460	17 940

The following acts are prohibited:

1. Allowing water to run to waste, or to run to prevent freezing.
2. Having leaky water fixtures on the premises.
3. Using a hose without a nozzle.

4. Using a nozzle with an orifice of more than one fourth of an inch.

5. Using water through a hose unless hose is held in hand.

6. Using water through a hose between the hours of 9.00 A. M. and 5.00 P. M.

7. Using an automatic sprinkler at any time unless such sprinkler is connected on a meter.

8. Using water through a hose during the progress of a fire in the city, except upon the fire.

9. Using water through any plumbing fixtures without first applying for and obtaining permission for such use.

10. Allowing water to be taken from premises by persons having no right to its use.

11. Willful waste of water in any way.

PRIVATE FIRE PROTECTION AND INSURANCE RULES.

BY GORHAM DANA, MANAGER, UNDERWRITERS' BUREAU OF NEW ENGLAND, BOSTON, MASS.

[*Read November 11, 1908.*]

In the work of laying out private fire protection for manufacturing and mercantile buildings, the insurance engineer frequently meets with opposition from the water departments. From my experience in this work, covering nearly fifteen years, I think it safe to assume that most of the water-works superintendents look upon an insurance engineer as an unreasonable fellow, who has all sorts of ridiculous rules, and whose main object is to get all he can out of the water department for himself or his client without giving anything in return.

It occurred to me that a frank explanation of the scope of our work and the reasons for our requests might put them in a better light before you and clear up some of the past differences in opinion.

As a matter of fact, the insurance engineer is not as unreasonable as he may appear. What he asks is from no selfish motive, for improved protection means lower insurance rates and less income for the insurance companies. The average local insurance agent prefers not to see sprinklers installed in the buildings he insures, for it means less premium to him.

What the insurance engineer does for one plant or individual is of benefit to the whole community, for it means lessening the chance of a serious fire, and, therefore, lower insurance rates for all.

The rules that he works under are no arbitrary rulings made by himself or by his manager, but they are National Standard rules drawn up by committees of the National Fire Protection Association. These committees are composed of men from all over the country and represent the experience and best thought of the brightest men in the business.

First of all, I should like to touch on the need of private fire protection, more especially automatic sprinklers, as a means of

reducing the annual fire loss of the country. That there is a need of reducing the fire waste must be apparent to any one who reads the ever-increasing list of fires in the daily papers. The total loss for the last thirty-three years has been four and one-half billion dollars. The average loss for the last few years has been almost two hundred and fifty million dollars. In other words, this loss is going on day and night at an average rate of $500 per minute. This is a direct and real loss to the community, the insurance only distributing the loss amongst many, and not really paying it. To this should be added the indirect loss of some $350 000 000 a year, due to the cost of maintaining fire departments, insurance companies, protective departments, fire-service mains, etc., so that the total fire tax to the country is something like $600 000 000 per year.

But the most discouraging feature of the situation is the fact that this loss is increasing each year by leaps and bounds. In 1875 the loss was only $78 000 000; in 1885 it was $102 000 000; in 1895 it was $142 000 000; in 1906 (the year of the San Francisco conflagration) it was $500 000 000. The loss for August, 1908, is estimated at $23 000 000, or $3 000 000 more than for August, 1907; and for September, $22,000 000, or $9 000 000 more than last year. That this country is far ahead of any other country in fire waste is shown by the fact that the loss per capita is $2.47, while in Germany it is 49 cents, in Italy it is 12 cents, and the average for European countries is 33 cents.

With these astonishing figures staring us in the face, is it not the duty of every one, water-works man, insurance man and all, — to do all in his power to reduce this ever-growing tax?

A large part of this loss occurs in our cities. American cities are growing at a tremendous rate, especially vertically, and our fire-fighting facilities are not keeping pace with the growth. This was well illustrated in the Parker Building fire in New York last winter. Here was a modern twelve-story building of so-called fireproof construction, but used for printing and similar purposes, and containing a large amount of combustible material. To be sure, it had the serious defect of large unprotected stair and elevator openings, but this is a defect that is very common in modern buildings. Fire started and gained some headway before being discovered. The

fire department responded promptly, but was utterly helpless above the eighth story and the fire on the upper floors practically burned itself out.

With this condition confronting us, what are we to expect in a twenty, thirty, or forty-two story building? So long as they are used for offices only, they are comparatively safe, but when filled with combustible material they can no longer be considered fireproof, even though the structures themselves are properly built.

If a conflagration should sweep lower New York, the loss would be in the billions, and probably every insurance company in the country would be put out of business. A panic would result such as the country has never seen.

What is the remedy for this state of affairs? Surely, a fire department now helpless above the eighth story cannot, for many years, at least, be developed so as to be effective at elevations of twenty and thirty stories. The remedy to my mind is the automatic sprinkler.

AUTOMATIC SPRINKLERS.

Sprinklers came into general use about twenty-five years ago, or in the early eighties. Since then they have been steadily improved, until now they have reached such a state of perfection that but little further improvement can be looked for. It is estimated that about 25 000 000 sprinklers have been installed in this country, representing an investment of almost $100 000 000.

Briefly stated, automatic sprinklers are small valves held closed by soft solder, melting at about 160 degrees. When opened, they distribute water by means of deflectors. They are placed throughout a building, 6 to 12 feet apart, and attached to pipes containing water under pressure. In unheated buildings, they are placed on the so-called dry system, a dry valve being introduced to hold back the water until a sprinkler head opens.

For twelve years the National Fire Protection Association has been collecting statistics on fires occurring in buildings equipped with automatic sprinklers. Six thousand and forty fires have been tabulated, and in 93.77 per cent. of these the sprinklers extinguished the fire or held it in check. In the other 6 per cent. they failed, but there was usually some good cause, such as closed

valves, empty tanks, etc. In 65 per cent. of the fires, 5 sprinklers or less opened; in 78 per cent., 10 sprinklers or less opened; in 91 per cent., 35 sprinklers or less opened.

Under normal conditions, sprinklers put out a fire with much less water than would be used by hose streams, and it would seem that for this reason alone water departments should welcome the introduction of sprinklers and do all they can to assist the insurance engineer in laying out a proper equipment.

RULES.

A few words about the rules for installing sprinklers may be of interest to some of you. Sprinkler systems to warrant the lowest insurance rate should have two independent sources of supply, so that if anything happens to one there will still be something to fall back upon. The ordinary supplies used are water-works connections, gravity tanks, pressure tanks, and various kind of pumps. Where pressure and volume are adequate, water-works systems are always considered the most desirable supplies. In fact, in large cities, where the public water supply is first-class, a proper sized connection from such a system is usually considered as good as a tank and pump supply in the country. There should be a pressure of at least twenty pounds on the highest sprinklers to give good protection. The size of main connections and risers is figured large enough to supply the sprinklers on one floor only, the theory of sprinkler protection being that they will control the fire on the floor where it originates. To this end great care is taken to enclose all floor openings, such as elevators and stairs, so that fire cannot readily spread from floor to floor.

The pipes on each floor are graded according to the number of heads supplied by each. The rules for these sizes have been evolved during the last twenty-five years from actual experience and tests. They were changed in 1896 and again in 1905, the sizes being enlarged both times, but the rules as they stand to-day will probably not need any further change of any importance, at least for many years. At present, a 4-inch pipe can feed 80 heads; a 5-inch pipe, 80 to 140; and a 6-inch pipe, 140 to 200 on a floor. Two hundred is as many heads as are often found on one floor between fire walls, and where this number is exceeded, two or more connec-

tions are generally called for. The distance apart that heads are located varies greatly with the construction, but one head to 80 square feet is a rough average.

SIZE OF CONNECTION.

Some water departments object to allowing the proper size connection where the street main is small. This seems to me unwise, for in case of fire, water must be used, and sprinklers will put out the fire with less water than hose streams. If the connection is not large enough, the sprinklers may fail to do what is expected of them and hose streams will then have to be used in addition. Therefore, it appears to be economy for the water department to allow the proper size of connection, no matter what is the size of main.

In some cases a ruling has been made that no connection over four inches in size can be made, although more than one such connection can be had where necessary. This seems to me to be an unnecessary hardship on the taxpayer. In the first place, it generally introduces another gate and check valve, which adds to the expense as well as introducing another chance for trouble, due to valves being closed by mistake. It also means more friction loss.

The only reason I have heard for such a rule is that there is less chance of waste in case of a break. I fail to see why this is so, for if two 4-inch connections entered a building and were brought together to feed one 6-inch riser, a break in this riser would be fed by two 4-inch, pipes, which have a capacity of practically the same as one 6-inch, and in case of a break in the 4-inch, the water would come from each direction and would again be about the equivalent of one 6-inch. As a matter of fact, the chance of breakage in one of these large pipes is extremely small, and it would seem that the benefit from a good sprinkler system would more than offset any possible danger of wasting water at a time when it was needed elsewhere.

Another feature to be considered is the additional cost in case sprinkler supervisory apparatus is installed.

SPRINKLER SUPERVISORY APPARATUS.

Sprinkler supervisory apparatus has only been on the market about two years, but many equipments have been installed in

the larger cities, like Chicage, New York, and Boston. It has already proved its worth and undoubtedly has an important future. Briefly stated, the idea is to affix electrical contacts to all gate valves and other parts of sprinkler systems, in order to give an alarm in case any device is put out of order. Thus, the attachment on a gate valve (Fig. 1) gives an alarm in case the valve is

FIG. 1. A. D. T. CO. GATE VALVE ATTACHMENT.

c = case; d = case contact; e = rubber roller; ff = German silver springs; g = post for closing case contact.

This is designed to attach to a gate valve so as to give an alarm as soon as any one starts to close the valve.

turned more than a fraction of a turn from the position of wide open. The attachment on a gravity tank gives an alarm in case the water level drops below a pre-determined point or in case the temperature gets too near freezing (Fig. 2). The attachment on a pressure tank gives an alarm in case the pressure or water level drop too low. The attachments are so made that they cannot be tampered with and the wiring is on a closed circuit and enclosed in conduit. The wires run to a central station where there are men on duty at all times. In case an alarm comes in, a runner is sent

to see what the trouble is and to remain until it is remedied, when necessary.

With such an equipment, it is almost impossible for a sprinkler system to become crippled in any way, without the trouble being discovered and remedied at once. The chance of sprinkler failures should thus be reduced to almost nothing.

Now each contact, that is, the attachment to gate valve, tank, etc., costs from $25 to $40 a year, and any extra valves required by water departments become a serious question financially. Furthermore, on account of the large number of sprinkler valves that are left closed accidentally where there are no such attachments, the underwriters prefer that as few as possible be installed.

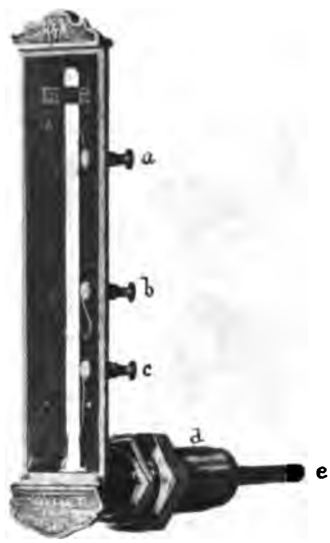


FIG. 2. A. D. T. TEMPERATURE DEVICE.

a = high-temperature contact binding post; b = low-temperature binding post; c = constant binding post.

This is designed to attach to a gravity tank to give an alarm in case pressure nears boiling point or freezing point.

METERS.

A few water departments in New England are requiring meters in private fire pipes. The underwriters are opposed to this practice on account of the numerous complications it introduces, principally friction loss, chance of clogging, and a considerable extra expense. It is true that the so-called detector meters have overcome the trouble of complications to a large extent, but they are expensive, especially in the larger sizes.

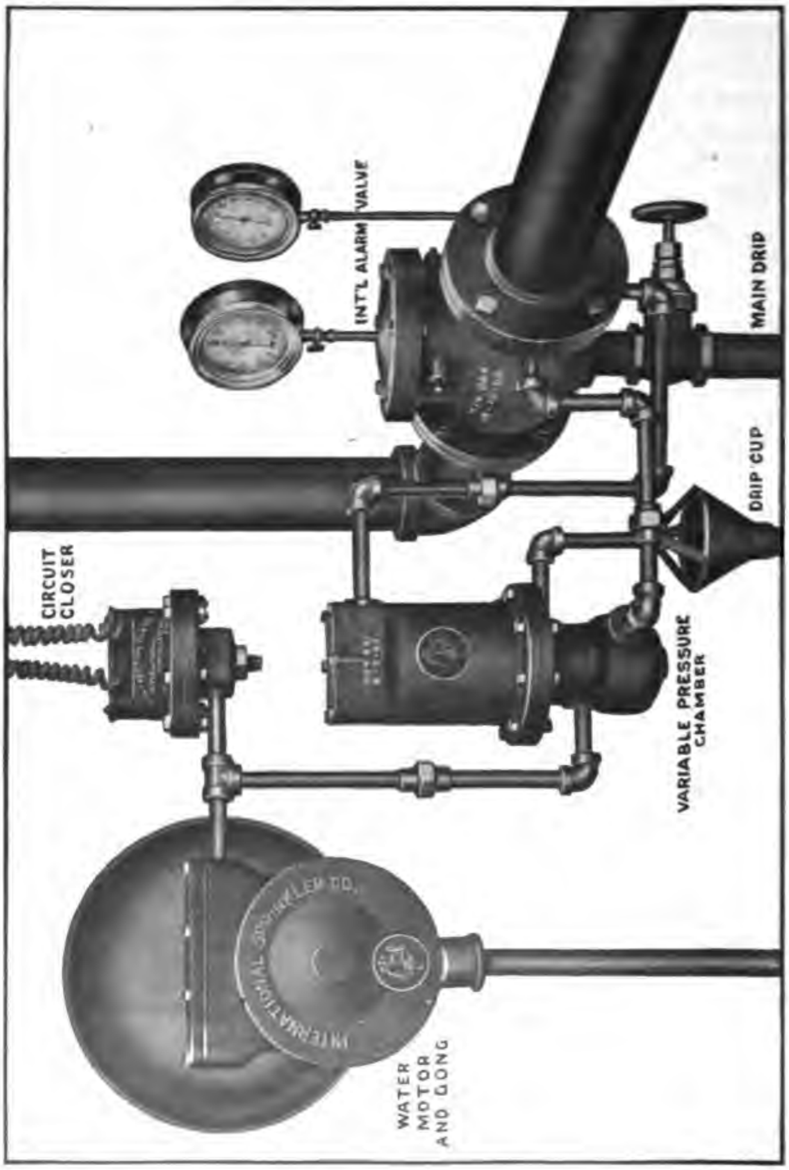


FIG. 3. INTERNATIONAL ALARM VALVE (GENERAL VIEW).

I realize that water is sometimes stolen from sprinkler systems, and that it is the duty of the water department to put a stop to it, but I believe there are other methods of accomplishing this result which are better from a fire protection standpoint.

In the first place, the insurance rules do not allow sprinkler pipes to be used for any other purpose. All water departments should have a similar rule and should enforce it rigidly. In addition, they may seal all drip valves and private hydrants and require that they be notified if a seal has to be broken for any reason. This is done in some cities, and, so far as I know, has successfully prevented any serious trouble.

Few people will steal water willfully. The trouble is generally caused by some engineer or mechanic who taps a fire pipe thoughtlessly, without realizing what he is doing. A pipe cannot be readily tapped without shutting off the water, and this would be brought to the attention of the department by the breaking of seals.

ALARM VALVES.

Nearly all modern sprinkler systems contain alarm valves. These constitute one of the best safeguards against taking water from sprinkler pipes that there is. There are at present two approved alarm valves on the market, the Variable Pressure or English Alarm Valve, made by the General Fire Extinguisher Company, and the International, made by the International Sprinkler Company. The principle in each is similar, namely, a check valve that when on its seat closes a groove or pipe outlet, and when off its seat allows water to flow into the groove or pipe. This water is used to give an alarm by operating a rotary or water motor gong, or by pushing up a diaphragm which gives an electric alarm. Alarm valves have been developed so that now they are very reliable, and furthermore, unlike the older types, they seldom give false alarms. The "International" and "Grinnell" alarm valves are shown in Figs. 3, 4, 5, and 6.

Now an alarm valve placed in a sprinkler pipe is, to my mind, just as good as a meter. No water can pass through the pipe without giving an alarm, provided the alarms are in order. The insurance inspectors go through the plant several times a year

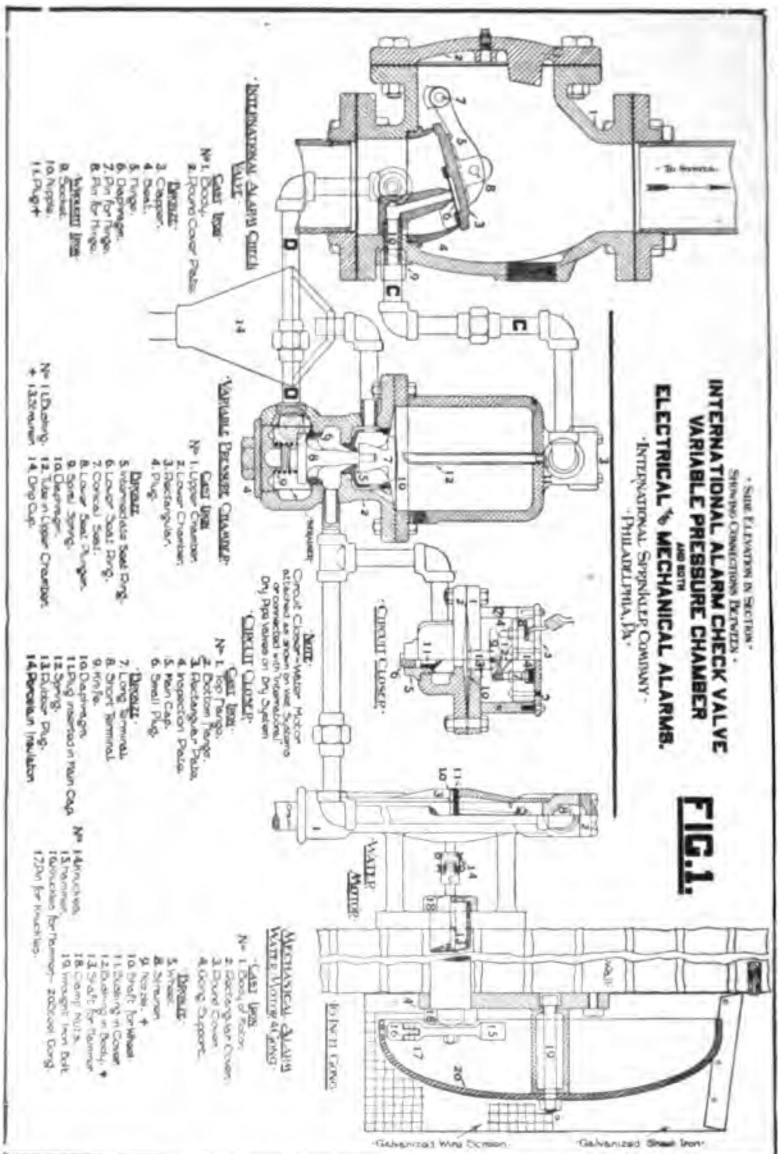


FIG. 4. INTERNATIONAL ALARM VALVE (SECTIONAL VIEW).

The swing check valve 8 tightly closes the outlet of pipe *C* when on its seat. When the check opens, water flows through pipe *C* to variable pressure chamber, hence to electric circuit closer and water motor.

to see that these are kept in order. In cities where there is sprinkler supervisory, such devices can be supervised from a central station, in which case a trouble signal is received if any part of the system gets out of order. If further proof is needed, small-sized meters ($\frac{1}{2}$ or $\frac{3}{4}$ in.) can be placed in the pipe that runs to the alarm connection. In this case, no water can be drawn through the sprinkler pipe without registering on this meter. This does not give the actual amount passing through the system, but the proportion could be roughly figured. In case there is a rule forbidding the use of any water, the amount is not important, for the rule is broken and the person who does it can be punished.

Still another method of checking up the flow of water in a sprinkler system is to place a recording pressure gage on the pipe from the alarm valve. Ordinarily there is no pressure in this pipe, the inlet being closed by the check valve. In case of flowage, the pressure will be recorded on the gage and the exact length of time that it occurred can be ascertained from the dial.

CHARGING FOR FIRE PIPES.

In some localities an annual charge is made for sprinkler connections from water-works systems. It might be argued that this is something that should not interest the insurance engineer, but anything that adds to the expense of a sprinkler equipment interests the insurance engineer, for it is his duty to keep the cost of such equipments as low as possible, so that they may be more generally installed and thus cut down the fearful annual fire waste.

Where a water-works system is owned by a town or city and supported by public taxes, there appears to be no more reason for charging for private fire service than for public protection. It may be thought best to make the property owner pay for the original cost of installing such a connection, but it certainly seems wrong to charge him any annual rental. This is, of course, assuming that the fire service pipes are used for fire protection only, as they should be.

The property owner is entitled to public fire protection on account of the taxes he pays. If he chooses to put in at considerable expense private fire protection that will put out a fire

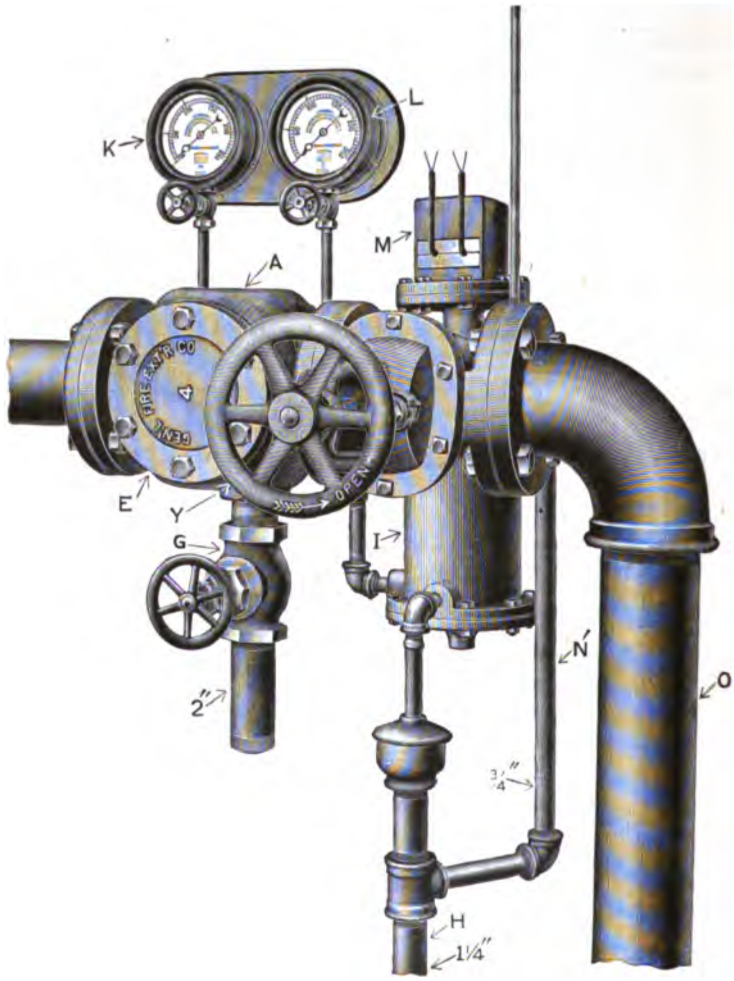


FIG. 5. GENERAL VIEW, GRINNELL VARIABLE PRESSURE ALARM VALVE.

with the use of much less water than would be used by fire department, it is certainly not fair to make him pay the community for so doing.

Where the water system is owned by a private corporation the problem is somewhat different. In this case the town usually

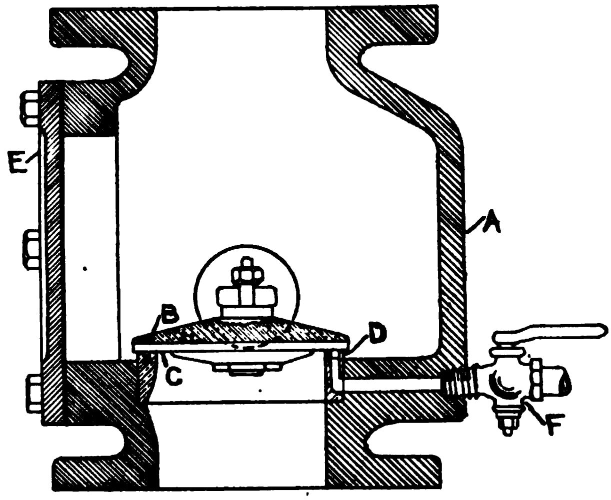


FIG. 6. SECTIONAL VIEW, GRINNELL VARIABLE PRESSURE ALARM VALVE.

The swing check valve *B* when on its seat closes groove *D*. When check opens the water flows through groove and pipe *F* to rotary bell and electric circuit closer (not shown).

pays the water company a given amount per year for each hydrant. Now there seems to be no reason why the private connection should not be placed on the same basis as hydrants in this case, too. If a mill owner should ask for more public hydrants near his plant, they would be supplied without cost to him. If, therefore, he asks for a sprinkler connection which will put out the fire with less water, why should he not be supplied with that, too, at the town's expense? As in the previous case, this is on the supposition that the sprinkler connection will be used for fire purposes only. The regular service connection should be entirely separate. If he desires more yard hydrants, these, too, might be well supplied at public expense, at least, so far as annual rental is concerned, for such hydrants are simply an extension of the pubpublic hydrant system, and this he is entitled to if he pays taxes.

Now as to the best basis for payment for fire service connec-

tions where the water system is owned by a private corporation, — for it is certainly fair that some payment be made, whether it be by the town or by the property owner:

In the past, systems have often been charged for on a basis of so much per sprinkler. This is unfair for the reason that sprinklers are installed on the theory that only one floor will be on fire at once. Sprinklers will almost always control a fire before it spreads to another floor, and if they do allow it to spread to this extent, the chances are that they will not control it at all. The same size connection and riser is allowed for a ten-story building as for a one-story building, provided the floor areas are the same. Only so much water can be obtained from a given sized pipe, whether it supplies ten stories or one.

Another method favored by some water companies is to charge a certain proportion of the insurance carried or a proportion of the reduction in rate allowed by the insurance companies for the protection. This is also unfair. It might be that a large part of the insurable value at the plant was in storehouses that contained no fire protection. Again, the reduction in rate for improved fire protection is not based on the protection afforded by public water connections only, but also on private water supplies, such as pumps and tanks, upon private brigades, private hose, watchman's service, and numerous other features.

The fairest basis for the charge would seem to be that of the number and size of connections, for it is this that determines the amount of water that could be used in such a system.

It would seem fair to consider a 4-inch connection as about the equivalent of one hydrant, for this is the smallest size of pipe permitted for a hydrant supply. On this basis a 6-inch pipe would be the equivalent of two hydrants, and an 8-inch pipe to four hydrants, a 10-inch to six hydrants, etc., this being figured on the relative area of these pipes. If, therefore, the price charged per hydrant be taken as a standard, and the sprinkler connection figured on the above basis, we would have a simple method of computation, yet one that is fair both to the property owner and the water corporation.

Finally I would impress upon you the need of coöperating with

the insurance engineer in his campaign to reduce the $500 per minute fire waste of the country. Do nothing that will discourage automatic sprinklers or make equipments more expensive, for in them lies one of the greatest safeguards against serious fires and conflagrations.

DISCUSSION.

MR. ANDREW D. FULLER.* I should like to ask Mr. Dana what the objection would be to metering the fire service where you have a tank.

MR. DANA. There is no objection to metering the supply which fills the tank, but for the supply which goes directly to the sprinklers, of course, the pipes have to be large pipes, 4 to 6 inches, and that means an expensive meter and friction loss and possible clogging in case of fire.

MR. FULLER. Then a person could have a sprinkler system installed, and pay for the amount of water necessary to fill the tank in the beginning, and then, if the direct supply was metered, he would not have to pay for any more water unless there was a fire. Would it not be practical to have the water company buy the large meter and charge a certain amount of rental a year, to cover depreciation, etc.? Would that cost more than the saving in rates?

MR. DANA. Of course it can be done, but what we claim is that it is not necessary, as there are other methods of getting the same results which are cheaper and, from our standpoint, better. We want to keep the cost as low as possible.

MR. CHARLES W. SHERMAN.† What Mr. Dana has said about the parties who pay taxes being entitled to the fullest measure of fire protection seems to call for a little comment. As far as my knowledge of them extends, most public water systems receive no help from the tax levy; they are entirely dependent for their operating expenses and for their contributions to sinking fund upon their water rates. Therefore no taxpayer *as such* is entitled to fire protection, since he is not paying for it. To be sure, the plant belongs to the community, which has loaned its credit for

* Civil Engineer, Boston, Mass.
† Principal Assistant Engineer, with Metcalf & Eddy, Boston, Mass.

the purchase or construction of the plant, but otherwise to all intents and purposes it has no ownership in the system. The water takers are the people who must foot the bills for the operating and maintenance expenses and the contributions to the sinking fund to extinguish the indebtedness.

Now, under those circumstances, as I said before, no taxpayer as such has any right to claim fire protection from the water-works. We are accustomed to furnishing it, and I do not see how we can very well change the conditions which confront us, but as a matter of equity a certain percentage of the necessary running expenses of the water system should be contributed from the tax levy to the water department. That would mean, of course, lower water rates to the private consumers, in order to get an equitable distribution of the operating expense between the water customers and the general public who should pay for furnishing fire protection.

MR. ELBERT E. LOCHRIDGE.* I should like to bring out a point or two in connection with this discussion. As water-works people we have all heard the claims of the insurance engineers, and I think that water-works people in general are anxious to meet them. To carry out Mr. Sherman's point a little further, in any system the revenue is derived from money paid for water used, and the largest consumer in most cases, under the prevailing system of rates, pays the least proportionally; that is, he gets his water cheaper than the small consumer. The fire protection is purely an outside matter, which, in most cases, is not paid for by the municipality except as its credit is loaned, although hydrants and larger pipes must be put in, which are not necessary for the domestic supply but are only needed in case of fire. For that reason it seems to me perfectly fair that people who are directly benefited in their property should pay a certain amount for that particular benefit.

To take up another point, which has not been brought out directly, when the insurance engineer comes to the engineer or superintendent of the water department and asks for these things, he doesn't quite see why it is that we can't grant them, and we don't see why our rules, which are for the benefit, as we see it,

* Chief Engineer, Springfield, Mass., Water Works.

of the entire city, are not as just as their rules; — for instance, their rules that there must be two supplies, and particularly that certain sizes of pipe should be furnished. Now, I want to say that in our reconstruction there have been a number of insurance engineers who have done everything they could to help us and who have arranged their plants in such a way as to insure safety as far as possible; however, there are some who do insist on points of which we cannot see the justice.

For example, two systems of water supply, as has been touched upon here already, are required by the underwriters. The city is under obligation to its citizens to furnish plenty of water for domestic purposes, and to have that water pure. Now, if a fire insurance company insists on two supplies, and allows the insured to pump from the Merrimac or the Connecticut River, or any other supply that is near the plant, as they do, and pump this against a check-valve, doesn't it seem reasonable that the company should also insist that these devices which have been described should be put on? But these are not put on in a great many cases, and so far as we are concerned personally we are having considerable trouble in getting some of them put on. I think we shall succeed in time. There is a constant menace in the testing of the pumps which, as they usually say, they simply turn over, but when you look at their dials you see that they usually go higher than the city pressure, or they do occasionally; and it seems to me perfectly reasonable that if these systems are to be thus connected it should be the duty of the insurance people to see that they are so connected that no impure water should go in for the use of the people employed in the mill or should go to the mains in the immediate vicinity of the mill.

I want to take up, also, not for the sake of argument but for the sake of putting forward the other view, the question of limiting the size of the pipes which go to the fire services. I don't care to consider the question of the actual sizes which should be used, but I think it is perfectly reasonable that pipes should be limited in size, and if greater capacity is needed I think it is perfectly reasonable that more pipes should be installed. If we have in the street an 8-inch main and an 8-inch connection, and the fire spreads beyond the immediate building in which the sprinkler

system is installed, we are under obligation to the other tax-payers and to the other water users to protect their property, and it is a serious thing when a large connection is left open on a street where the gridironing system is not perfect, — and in most of our New England cities it is not perfect in all parts of the factory district. On the other hand, it is probable that with two or more openings they be so placed that even with an advancing fire one of them may be shut off, and it is also possible that as the fire advances both of them may be shut off; and if you can reduce the opening to a 4-inch or a 6-inch instead of having it the full 8-inch, you have gained that much. I believe that the sprinkler system is of great value, and I think that the water-works officials should be ready to meet the insurance people half way, but I believe also the insurance engineers should meet the water department half way in its efforts to meet the demands for pure water, and in its demands that the least amount of water possible should be furnished for private fire protection alone.

Just one other point which occurs to me, and that is that the factories using fire supplies do not willfully take water. I think that the only thing we can fairly say is that they may not *willfully* take it, but if you go about you will see that they do take it, and every water-works man present knows that they take it in pretty large quantities. When we go around with our inspectors we know there are some very decided uses. It seems to me, then, that the insurance engineer should be ready, when asking for the concession of no meters and larger pipes, to furnish such guarantees to the water department that the department would not always be regarding these requests with suspicion, with the knowledge that in the past a great deal of water has gotten by.

MR. DANA. Mr. President, I should like to reply very briefly to Mr. Sherman. The main point in regard to cost and charging to my mind is that of putting private service on the same basis as public service. Whether or not an abutter should pay for hydrants I do not know, and I am not discussing that; but I do claim that if he does not pay for hydrants he should not be asked to pay for a connection to his building which will put out a fire with less water than he would take from the hydrant.

MR. EDWIN C. BROOKS.* Mr. President, I have sometimes thought that some of the trouble in regard to sprinkler systems might be solved by putting in composition check valves. The body of a check valve, as ordinarily made of cast iron, is barely large enough to let the valve operate, and the least formation of tubercles on the inside of the body is liable to arrest the opening or closing. Now a composition check valve would not be a very expensive luxury, and it seems to me it would be a step in the right direction in solving the trouble arising from check valves sticking open. Any one who has ever had much experience with check valves knows that they are an invention of the devil, and at best they are a very poor contrivance.

MR. EDWARD V. FRENCH.* Mr. President, I used to come here simply as an insurance man, and I got pretty good treatment then, though generally not a great deal of agreement. I am glad to come to-day more as one of the brotherhood, for as one of the members of the Water Board down in Lynn I think I have had enough trouble during the last year or two to feel pretty secure in the ranks, — and the trouble is not over.

I would like to emphasize a little one point which Mr. Dana made in answering Mr. Sherman. Mr. Sherman's points are, I think, entirely right, if you analyze this question of charges for fire service down to the final limit, but his suggestions are not feasible, apparently, under present conditions of organization, as Mr. Sherman himself really intimated. I have brought up this illustration before, but I think it makes the thing clear. Take any one of our cities, and suppose at one end of the city there is a manufacturing plant that has no fire protection of its own, and simply depends on the public water supply. If that establishment gets on fire, there isn't anybody here who questions that it is the duty of the public fire department to go down there and throw water on that plant for six or eight hours, or longer if necessary, and to use all the water that they can get; and frequently, where the fire has to be extinguished by such methods, the amount of water used is large. Now, supposing at the other end of the same city there is a progressive sort of a manufacturer, who has listened to some of the

* Vice-President Arkwright, Mutual Fire Insurance Company, and member of Water Board, Lynn, Mass.

ideas of men like Mr. Dana and put in private fire protection. If he has a plant that is worth $500 000, the chances are that he will have spent $20 000 of his own money for fire protection. He goes to the city and asks merely for a connection to supply his sprinklers with water, and immediately there is a desire to charge an annual amount for the service. Now the fact is that this manufacturer after spending his own money for protecting his plant is very much less likely to use any considerable amount of water than the man at the other end of the town who has no protection whatever. So that, as a matter of equity, with our present method of charging, it really is not fair to charge a man who is progressive enough to put in a fire equipment, which means merely better tools for using the water that is there, and let the man at the other end of the town have all the water that can be thrown on his plant without making him any charge whatever.

I am perfectly ready to agree — and I wish in our own case we could get something out of the tax levy—that it would be equitable to have the water department paid so much from the city funds for the fire service which it renders. Until that can be done, however, it isn't really fair and equitable to ask a large yearly payment from the man who puts in protection for the connection he desires to supply his equipment, and let the other man who perhaps does not pay any more to the water department get his fire protection perfectly free. It is simply a question of the equity of the thing under the present imperfect arrangement of charges.

Now just a word as to what Mr. Lochridge has said. I generally agree pretty well with Mr. Lochridge, and I think we will agree in this case. The real cardinal point about the sizes of connections is this: In order to make the sprinkler equipment at all efficient, you have got to furnish a fair amount of water at the outset of the fire. Fires that open 25 to 50 sprinklers are not uncommon. I have a list here of a good many fires in the last year and a half which opened over 25 sprinklers. Now 15 gallons per sprinkler is about the minimum, so that 50 sprinklers would take 750 gallons,—and we have rather taken for the average size plant 750 gallons a minute as about a fairly good water supply, if it can be delivered at a pressure of, say, 10 or 15 pounds at the highest head while the

sprinklers are discharging. If you stop to figure you will find that a 4-inch pipe, which will generally be 50 feet long between the street main and the fire service, together with the check valve and a gate and perhaps one or two elbows, will cause a loss of about 25 pounds pressure with 750 gallons per minute flowing. If, on the other hand, the service is 6-inch, the pressure loss comes down to a few pounds. Again, if you have a larger plant which may require, say, 1 500 gallons a minute, the loss in a 4-inch pipe would be in the vicinity of 100 pounds, which is absolutely prohibitive.

I agree fully with Mr. Lochridge that it is the duty of the water department to safeguard the whole system, but you never can do it perfectly, or even very efficiently, by simply putting in small-size connections. I think the rule should be to limit the connection reasonably to a size which would give the water needed in the particular case, and then get safety by requiring such a location of these connections and such controlling valve, that the valve can be gotten at and the water shut off in case the building falls.

In a great many factory plants the water goes into a system of yard pipes and is there distributed to the buildings, and every sprinkler connection has an outside valve, so that all use of water can be controlled. In the more compact sections of a city where there are built-up districts, so that you cannot do this, I think it would be possible for water departments, and perhaps this Association can help in that line, to develop some standard method of outside valves, marked in some standard way, so that it would be known as an outside controlling valve, and then locate those with a little study in each special case, so that they could be reached properly. This, I think, would give the protection needed, and is really the only way to get it in a thoroughly safe manner.

Mr. Brooks brought up another interesting point, which Mr. Lochridge touched on also, and that is the check-valve and its diabolical origin. I think he is entirely right about it. We have given this much study, and it is possible to get a check-valve of better design, with more clearance, so that tubercles cannot easily obstruct it, and with better hinges, etc. We have given a good deal of attention to having such a check put on the market and are using such improved patterns in places where there is

* Superintendent of Water Works, Cambridge, Mass.

danger of pollution. In cases where the danger is considered serious we are putting in two checks in series, one after the other, and putting them in a pit so that they can easily be kept in order. I believe in this way the conditions can be made very safe. The underwriters are ready to meet water-works men on all these matters, and fully appreciate that our interests are identical. I believe it will be seldom, when we get together in this way, on most anything except meters, that we shall fail to work out the problem in a manner satisfactory to all interests.

MR. JOHN H. FLYNN.* I had occasion not a great while ago to go to a place where they had all these devices which have been spoken of, and the owner laid great stress on the fact that he had wonderful protection because he had three 4-inch pipes going into his building. Two of them, however, were found to be shut off out in the street, and had been for three years; in fact they had never been opened.†

MR. M. F. COLLINS.‡ Mr. Dana has told us here to-day that where there are two sources of supply run into a building the cost of insurance is at the minimum. Now, if in a case where two supplies go into a building, we will say the high and the low service, the parties get their insurance reduced to such a low figure, why shouldn't they be willing to pay for one of the services, when they have two and it reduces their cost of insurance so much? I know of a case in our city where the owner of the building wanted to get the high service put in for nothing, and he was frank enough to tell me that it would bring his insurance down $600 a year, and notwithstanding that he wasn't willing to pay a yearly rental of $25 for a 4-inch connection. I should like to have Mr. Dana explain that.

MR. DANA. I don't know why a high and low service supply should be any different from a single service; the principle is the same. The question is why you should want to make a man pay for putting a system in his building which will extinguish a fire with less water than would be used from the hydrants. I

* Assistant Superintendent, Boston Water Works.

† (*Note by* MR. DANA.) It was supposed that these valves had been left open by the water department, and the discovery that they were closed was made by an insurance inspector.

‡ Superintendent of Water Works, Lawrence, Mass.

don't see that it makes any difference whether he has one or two connections.

Mr. Collins. In the case to which I refer, the man had the low service system in, and the high service was extended down through the business portion of the town at the expense of the public. There was a special appropriation made; the money for the extension was not taken out of the water department. He had all the protection that it was originally intended anybody should have by the low service, which gave in the neighborhood of 65 or 70 pounds pressure; but he asked for the other to be put in on the ground that it would reduce his insurance. Now, if it reduces his insurance why shouldn't he be compelled to pay for it, and why should the insurance engineers be so particular to look after his interests rather than to look after the interests of the water department?

Mr. Dana. I think the same argument will hold, that as matter of principle it doesn't make any difference whether there is one or two services. The question is, if that high service is put in for fire protection, why he hasn't as much right to use it as the next man has. It would be used in case of fire anyway, and if he has a sprinkler system connected with it he will use less water in case of fire than if he hasn't.

Mr. Collins. That doesn't answer the question. My question was, why shouldn't he be willing to pay for the double system, as long as he gets a reduction in his insurance rate? If he gets a reduction of $600 a year in that, why shouldn't he be willing to pay a proportionate part of the expense that the city has to pay?

Mr. Dana. Simply because the high service is put in for public protection.

Mr. Collins. But it isn't public protection when he gets it inside his own building.

Mr. Dana. I don't know why it isn't. If the water puts out any fire it has to go inside the building, of course.

Mr. Flynn. I have a case in mind where a building fell down and carried the pipe with it. It fell down in front of the stairway leading up into the building, and there was a 6-inch pipe running up that stairway. The side walls of the building fell

down and covered the gate in the street, and it was three days before they got the brick away from it, and of course the firemen had gone home long before that. It seems to me that there was a loss there

MR. DANA. You should have your valve in the street, so you can shut it off from the street.

MR. FLYNN. But we couldn't get at it, because the side wall of the building fell over and covered it up with about 20 feet of brick.

MR. DANA. They couldn't get at the valves after the San Francisco earthquake, but such cases don't happen very often.

MR. FLYNN. We have to look out for the one case that does happen, — that is when we are proficient in our business.

MR. DEXTER BRACKETT.* I should like to ask the insurance engineers if they think it would be practicable to shut off fire pipes during the progress of a large conflagration in the business section of Boston, on Washington Street, for example, or on any of the streets that are solidly built upon, in case the buildings were destroyed. It does not seem to me that it would be, and I think there is considerable to be said from the standpoint of the water-works superintendent who objects to putting in pipes of a large size for sprinkler service. The conditions must be taken into account. The conditions that are met by the Manufacturers Mutual Fire Insurance Company, and by other companies that insure largely mill property, where they have yard room in most cases, are entirely different from what they are in a thickly settled city. The quantity of water that is demanded for the sprinkler heads on one floor would be a small part of the quantity of water which would be discharged from a 4-inch or 6-inch main if the building burned, and under those conditions it is probable that the fire service in the immediate neighborhood would be crippled.

The remedy for this may be to have an entirely independent system of street pipes for supplying standpipes and sprinkler systems, independent of the domestic and hydrant service, and this has already been done in the business portion of the city of Boston. Wherever the property is of sufficient value to warrant

* Chief Engineer, Metropolitan Water Works, Boston, Mass.

this expense, it can be done. But I do not believe that the water-works authorities are warranted in crippling the system for the benefit of one comparatively small manufacturer. It may be a question of the comparative value of property. If the property to be protected is a plant worth $1 000 000, and property in the immediate neighborhood is worth but a few thousand, it may be policy to carry one or more 6-inch pipes into a building for supplying sprinklers, but I doubt the desirability of doing this in all cases.

MR. DANA. Mr. President, in reply to that I would simply suggest that the main point in the use of sprinklers is to prevent a fire from getting large, and we hope some day to have the cities in such shape that we won't have the large fires. When we get the buildings either all fireproof or all equipped with sprinklers, then we won't have any fires which will necessitate shutting off a connection.

MR. GEORGE CASSELL.* I am one of the very few men who have had a very wide and sorrowful fire experience. I want to ask Mr. Dana if he thinks the sprinkler system would have had the effect of putting out such a fire as struck my city [Chelsea, Mass.] on the 12th of April last?

MR. DANA. I don't think it would after the fire got well started, although a brick building properly equipped might have checked it in a certain direction. Sprinklers are supposed to prevent it getting started. The Brown-Durrell building in Boston was equipped with sprinklers and checked the big fire of March 10, 1893, which, but for this, would have undoubtedly been a conflagration.

Automatic sprinklers, together with open (window) sprinklers and blank walls, saved the O'Neill department store in the Baltimore fire and assisted in preventing the spread of the conflagration.

MR. CASSELL. That is just the point, "supposed." The inevitable is going to happen.

MR. DANA. Not when you get your whole city equipped.

MR. CASSELL. You couldn't have stopped a fire of that kind if you had had all the sprinkler systems and all the steamers in Massachusetts and an Atlantic ocean of fresh water.

* Superintendent of Water Works, Chelsea, Mass.

MR. DANA. You could if you had had sprinklers in the building where it started.

MR. CASSELL. But, my dear sir, you see you use that little word "if." There is the stumbling block, the "if." It did happen, didn't it?

MR. DANA. Yes, sir.

MR. CASSELL. It did; and that substantiates my position.

MR. DANA. 'What have you done since? You have required that all rag shops hereafter built in Chelsea shall be equipped with sprinklers, in order to prevent it happening again.

MR. CASSELL. That is the law, to be sure, and that brings up another point. You have said to the gentlemen gathered here this afternoon that you have laws governing fire protection systems; and so we have laws in our city, newly made and old, for the protection of property from fire; but the trouble is they are not enforced. Now, if your company, or whoever is interested — and there is a wide field for improvement —will get the coöperation of all the insurance men, and people who install the sprinkler systems, to adhere strictly to your rules and to our rules, we would all be much better off; but experience shows there is very little attention paid to them by some of the insurance people. They come into my city and they think that they are licensed to go into any place where there is a sprinkler system and do just as they please. I am not saying that you are to blame, nor that you are cognizant of the facts, but these are facts. And they had carried it to such a degree that a short time ago I brought some of them before the court and had them fined.

I am only citing this to show that if that hearty coöperation in all things of which you speak,— and by the way, you don't tell our side of it, you only tell your side of it, — if that hearty coöperation in all things pertaining to water supplies was entered into by the insurance people and the water-works people, we could get together and formulate some plan which would be of benefit.

I am glad Mr. Brackett spoke as he did in relation to private fire supplies, because we are well acquainted with the past, and we have had that up in our city, and while we are desirous of doing everything we possibly can do, not only for the corporations but

for the individuals, there is a point at which, when we arrive at it, we must stop. While we are willing to coöperate with the insurance men in furnishing a private fire supply that will not cripple the public supply in the vicinity, when it comes to their asking for something that has a chance to work an injury to the rest of the citizens, there we draw the line. And I say, and say it decidedly, that when the insurance people ask a water-works man to give them a supply of water from a main, in a district not perfectly gridironed, that is equal to the capacity of the main in the street, the man who gives it to them is putting himself in a position to be severely criticised in case of a serious conflagration.

Now, if the insurance people will pay more attention to their own rules and to our rules, they will help us out greatly. For them to make plans for the installation of a private system for a big factory in a city, go ahead with it, and then after they have finished it all come to the water office and ask for a connection, without having found out what our rules and regulations are, I say it is not right. They should come first and get the rules and regulations and the requirements of the city, and not get into trouble and then come and try to force the water department employees or officials to help them out by giving them something that is liable, and very much so, to be to the detriment of the other citizens who are entitled to fire protection.

Mr. Dana. Mr. President, in reply to Mr. Cassell, I will state that the principal reason why I am here to-day is to tell you our rules and to learn your rules and to help bring about better coöperation. I am sure we are always ready to comply with any reasonable rules, but the point is that we think some of your rules are unreasonable.

Mr. Cassell. And I think we have greater reason to believe that some of your rules are unreasonable.

The President. It seems to be the same old question between the insurance men and the water-works superintendents. We have had it up before and are liable to have it up again.

Mr. Collins. Mr. Dana in his paper spoke of going into some city, if I understood him correctly, and finding 200 gates closed.

Mr. Dana. Oh, no; that was not in one city; that was a year's

record in the whole of New England. They were private valves inside of buildings.

MR. COLLINS. Well, let me give you an idea how that may have happened. One day I was riding down Canal Street in our city and I saw a man closing a gate on the street. I pulled up my horse and asked him who he was, and he informed me that he represented the underwriters. I told him who I was, and said, "If you want to operate any of our gates it is our duty to furnish a man to go around with you." He said he wanted to make sure they were all right. I told him that where the authority was divided between the city officials and the mill officials nobody was responsible, and if he wanted to see anything we would give him all the help he needed; but if he went around and operated the gates and closed some of them and left some of them closed, I didn't think it would be the insurance company which would be held responsible, but the water department. So I was wondering whether in those cases of which Mr. Dana spoke it might as likely be the insurance men as the water-works men who were responsible.

MR. DANA. I think you were right; the man had no right to touch the gates without a water-works man present.

MR. GEORGE A. STACY.* I remember a somewhat similar instance in my town, Mr. President. A man who had charge of a large storehouse came to me one day and said, "We haven't got a main gate wrench up there at the storehouse." I said, "I didn't intend you should have; what do you want it for?" He said, "There is an insurance man here and he wanted to go out and try your gate on the street to see if it was open." I said, "He cannot, unless I go with him." "Well," he said, "the man said there ought to be one there so he could try the gate at any time."

I don't say this as a criticism of all insurance people, but there are some of them going around who, I think, haven't been in the business a great while. I have found the majority of them nice people to deal with. This young man wanted to take a wrench and go out unbeknown to me and handle one of my gates, and I told him, "Any time that the insurance people want to investigate any part of the works, if they will simply notify this de-

* Superintendent of Water Works, Marlboro, Mass.

partment we will drop everything and accommodate them to the best of our ability. They can open and close them as much as they like, but we want to be there when it is done." I think that is reasonable and right. I think he had no business to ask for that wrench, or to go and handle the gate, without me or my representative being there. That creates friction.

Every factory in our city is sprinklered, and there hasn't been an instance yet where the sprinklers haven't done their work, and I know of three or four pretty good-sized structures in the city of Marlboro which, there is no question in my mind, would not be standing there to-day if it wasn't for sprinklers.

On the subject of check valves, I have been interested in what has been said here. In the upper part of the city we have two systems, high and low, and I was rather in doubt how I was going to handle the question when they wanted both pressures available in the factories for their sprinkler service. We believe in doing everything that we can to secure lower insurance rates for our manufacturers, so long as we can do it without crippling the works; so we laid two service pipes, one from the high and one from the low, and put check valves into one outside the building. Those check valves were made by a firm not a great way from Boston. They were put in some years ago; there are quite a number of them; they have been tested many times and they have always worked and been perfectly tight and reliable.

There is one thing more which I recall, that occurred a long while ago, — I suppose they have got beyond that now, and I wouldn't question for a moment the ability of an insurance engineer of the present day to tell what the capacity of a pipe should be, — but there was this one very peculiar thing, that occurred perhaps fifteen years ago, in the upper part of the city, where there was 30 or 35 pounds at that time on the main; they wanted a 4-inch pipe for the sprinkler system, and later, perhaps two or three years afterwards, in the lower part of the city, where there was 95 pounds, for the same service,—practically the same size building with the same number of sprinklers,—I had to put in, or did put in, on request, a 6-inch pipe. I never could reconcile that. I don't mean to say that the insurance people didn't understand what they were doing, but those are the facts.

In regard to a second connection, we have always required the manufacturer to pay for it, and he has always done it willingly. In one case we went through three feet of frost to get the second pipe in by the time the insurance under the one-pipe system expired, and they were willing to pay the extra cost. We haven't had any trouble with our connections or our sprinklers or with the insurance men, except in a very few cases where I think anybody would say they were a little unreasonable. There is very little friction between us, and I think the time is coming when we will all get together. I think we are nearer on this matter of fire service pipes than we were, and everything will come out all right if we have a little patience and keep on with our discussions. I think we are coming to learn more every time we talk these matters over. I think the insurance men are learning, I won't say more than they now know, but a little more about our position, and we are learning a little more about theirs.

PROCEEDINGS.

November Meeting.

Hotel Brunswick, Boston, Mass.,
November 11, 1908.

President Alfred E. Martin in the chair.

The following members and guests were present:

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, George Cassell, J. C. Chase, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, G. W. Cutting, Jr., Gorham Dana, E. D. Eldredge, J. H. Flynn, F. F. Forbes, A. N. French, E. V. French, A. D. Fuller, F. L. Fuller, D. H. Gilderson, T. C. Gleason, A. S. Glover, F. H. Gunther, F. E. Hall, T. G. Hazard, Jr., H. G. Holden, J. L. Howard, C. L. Howes, W. S. Johnson, J. W. Kay, E. W. Kent, Willard Kent, G. A. Kimball, G. A. King, L. P. Kinnicutt, H. O. Lacount, E. E. Lochridge, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, F. L. Northrop, H. L. Newhall, E. M. Peck, J. H. Perkins, L. C. Robinson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, W. F. Sullivan, R. J. Thomas, D. N. Tower, W. H. Vaughn, R. S. Weston, J. C. Whitney, F. I. Winslow, G. E. Winslow. — 72.

Honorary Member.

William T. Sedgwick. — 1.

Associates.

Harold L. Bond Company, by Harold L. Bond; Central Foundry Company, by J. H. Morrison; Chapman Valve Manufacturing Company, by E. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by W. H. VanWinkle, G. W. Browne, and W. H. VanWinkle, Jr. — 15.

Guests.

John McKay, chief engineer, and Charles Rennie, chief inspector, Brooklyn water works, Brooklyn, N. Y.; T. Easten, chairman water board, and I. M.

Lowe, superintendent, Weymouth, Mass.; L. H. Camfel, Boston; W. M. Collins, M.D., and James E. Donnelly, Lowell, Mass.; R. W. Carter, water commissioner, Maynard, Mass.; J. A. Jones, superintendent, Stoneham, Mass., and Dr. H. D. Pease, director State Hygienic Laboratory, Albany, N. Y. — 10.

[Names counted twice — 3.]

Henry Roberts, of Hartford, Conn., president and superintendent of the Hartford water works, his application having been properly endorsed and acted upon, was elected a member of the Association.

Mr. Gorham Dana, manager of the Underwriters Bureau of New England, Boston, Mass., presented a paper entitled "Private Fire Protection and Insurance Rules." The paper was discussed by Messrs. Andrew D. Fuller, Charles W. Sherman, Elbert E. Lochridge, Edwin C. Brooks, Edward V. French, John H. Flynn, Dexter Brackett, George Cassell, and George A. Stacy.

Dr. H. D. Pease, director State Hygienic Laboratory, Albany, N. Y., presented a paper entitled, "Public Water Supplies of the State of New York," which was discussed by Messrs. Robert S. Weston, Wm. T. Sedgwick, Elbert E. Lochridge, and Leonard P. Kinnicutt.

Adjourned.

EXECUTIVE COMMITTEE.

NOVEMBER 11, 1908.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple.

Present: President Martin and members George A. King, D. N. Tower, Robert J. Thomas, George W. Batchelder, M. F. Collins, William F. Sullivan, Charles W. Sherman, L. M. Bancroft, Willard Kent, and George A. Stacy.

James R. Fitzpatrick, general manager Grand Rapids and Hydraulic Company, Grand Rapids, Mich., was reinstated to membership.

Application of Henry Roberts, president and superintendent Hartford water works, Hartford, Conn., was received and he was recommended for membership.

The Secretary was appointed a committee to investigate and report on Bangor as a place for holding the next annual convention.

WILLARD KENT, *Secretary.*

REPORT OF COMMITTEE ON EXHIBITS AT CONVENTION.

NOVEMBER 5, 1908.

WILLARD KENT, *Secretary,*

NEW ENGLAND WATER WORKS ASSOCIATION:

Sir, — The Committee on Exhibits at the annual convention at Atlantic City, hereby makes the following report.

Eighteen associates availed themselves of the opportunity to exhibit goods as follows:

International Steam Pump Company	Worthington meters.
Anderson Coupling Company	Lead connections.
Water Works Equipment Company	Tapping machines, etc.
H. Mueller Mfg. Company	Water-works specialities.
National Meter Company	Meters.
Hersey Mfg. Company	Meters.

Neptune Meter Company	Meters.
National Water Main Cleaning Company	Samples of pipe.
Builders Iron Foundry	Venturi meters, etc.
Lead-Lined Iron Pipe Company	Lead-lined pipe and fittings.
Pittsburg Meter Company	Meters.
A. P. Smith Mfg. Company	Tapping machines, etc.
Thomson Meter Company	Meters.
East Jersey Pipe Company	Lock-bar steel conduit pipe.
Union Water Meter Company	Meters.
Ross Valve Mfg. Company	Regulators, etc.
Hays Mfg. Company	Water-works specialities.
Fairbanks Company	Scales, hydrants, and valves.

Eighteen exhibits, occupying 500 square feet of space.

Respectfully submitted,

EDWARD F. HUGHES.

OBITUARY.

ARTHUR W. HUNKING died at Helena, Mont., on November 12, 1908, after an illness of a few days.

Mr. Hunking was born in 1851, in Haverhill, Mass. After graduating from the Haverhill High School he took the civil engineering course at the Massachusetts Institute of Technology. His first professional engagement was with Mr. Clemens Herschel, who then had his office in Boston, but he soon joined the staff of the Locks and Canals Company at Lowell, and, except for a year or two spent in the service of the Holyoke Water Power Company, was with that company until 1890. His later service was with the Stillwell-Bierce & Smith-Vaile Company, the Manufacturers Mutual Fire Insurance Company of Philadelphia, and the Massachusetts Cotton Mills in Georgia. In 1905 he became connected with Stone & Webster, of Boston, and was engaged on various water-power development work for them to the time of his death.

He was elected a member of the New England Water Works Association, June 11, 1890.

J. O. A. LAFOREST died December 28, 1907. He was born at Joliette, Quebec, in 1867, and graduated in 1885 from L'École Polytechnique in Montreal He was first employed as an engineer upon the Great Northern Railway of Canada. In 1889 he became assistant engineer of the Montreal Water Works, and in 1894, general superintendent, holding this position for six years. Later he was engineer in charge of construction of water works at a number of towns in Quebec, and from 1903 to 1907 he was in charge of harbor works at Louise Basin, Quebec. He was a member of the Canadian Society of Civil Engineers.

Mr. Laforest became a member of the New England Water Works Association, December 14, 1892.

CLAUDE PENDLETON NIBECKER, sanitary engineer for the American Water Works and Guarantee Company, died in Pittsburg, Pa., November 10, 1908.

He was born at Westerly, R. I., September 19, 1881. He was graduated from the Massachusetts Institute of Technology in 1903, and immediately thereafter was employed on the experimental filters of the Springfield, Mass., water works. At the close of this work he was engaged by the American Water Works & Guarantee Company, and remained with this company until his death.

Mr. Nibecker was elected a member of the New England Water Works Association on November 14, 1906.

BOOK REVIEWS.

SEWER CONSTRUCTION. By Henry N. Ogden, Professor of Sanitary Engineering, Cornell University. 6 x 9 inches, xii + 335 pages. New York: John Wiley & Sons. Price, $3.00.

This book is supplementary to the author's "Sewer Design," which was published in 1899, and is the result of a course of lectures given to students in civil engineering at Cornell University. It is, therefore, to a large extent, of an elementary nature, but is intended to be, and unquestionably will be, useful to practicing engineers who are for the first time taking up sewer construction work, as well as to students.

Some idea of the contents of the book may be obtained from the titles of the chapters, which are as follows: Terra-Cotta Pipe, Terra-Cotta Pipe (continued), Brick Sewers, Concrete Sewers, Concrete and Brick Sewers, Reinforced Concrete Sewers, Manholes, Catch-Basins, Siphons, Screens, Storm Water Overflows and Regulators, Bell-Mouths, Foundations, Outfall Sewers, House Connections, Surveying, Trenching, Estimates and Costs, Specifications and Contracts.

The treatment of the several subjects is as full as could be expected for students' use, but the practicing engineer would desire somewhat further information on some points, particularly on the design and construction of forms for concrete and reinforced concrete sewers. Some of the statements relating to rapidity of work, too, seem to have been based upon experience prior to the adoption of the eight-hour day, and are hardly applicable to present conditions, at least in New England.

The book is not only well adapted, as a whole, for the classes for whom it was especially prepared, but is well worthy of the perusal of engineers who are actively engaged in this class of work; most of them will find suggestions or ideas which are new or helpful to them.

RESERVOIRS FOR IRRIGATION, WATER POWER, AND DOMESTIC WATER SUPPLY. By James D. Schuyler. Second edition, revised and enlarged. 573 pp. 6¾ x 10 inches. 381 illustrations, 6 plates. New York: John Wiley & Sons, 1908. $6.00.

This second edition of Schuyler's "Reservoirs" has been much enlarged and largely rewritten. The demand which has resulted in the revision is an evidence of the favor with which this work has been received. The reviewer heartily welcomes the new edition, which contains a great deal of information not easily obtainable elsewhere, and of great interest and value to all who have to do with the design, construction or maintenance of dams or reservoirs. And yet there are many things that may be criticised.

In the first place, the book might more properly be entitled "Dams and Embankments," since it treats almost exclusively of those subjects. Very, very little is said about reservoirs, and nothing whatever about the relative advantages of deep and shallow reservoirs, necessity or otherwise of clearing, grubbing or stripping, estimation of capacity, or other subjects relating to reservoirs rather than dams. Indeed, the chapter titles and section headings are almost invariably *dams*.

The chapters are as follows: Rock-Fill Dams, Hydraulic-Fill Dams, Masonry Dams, Earthern Dams, Steel Dams, Reinforced Concrete Dams, Natural Reservoirs, Miscellaneous.

The basis of the book is a large number of illustrations, largely reproductions of photographs of dams, with a reasonable number of cross-sections and plans, and with comparatively brief sections of descriptive matter. Something like 300 dams are thus described. In some cases the descriptions are fairly detailed, and cover several pages.

There does not seem to be any logical scheme of arrangement of either chapters or sections. The several matters are not treated in chronological order, nor are they grouped at all closely by types or forms. Thus we find gravity and arched masonry dams mixed indiscriminately in the chapter on masonry dams. There are also certain peculiar arrangements, such as inserting a plate showing irrigation canals near Phœnix, Ariz., in a description of dams in Old Mexico; a map of sources of water supply near San Diego, Cal., in text describing dams in India; a cut of the cross-section of the earthern part of the Ashokan dam, without description, in the chapter on Masonry Dams, etc.

The book is made up almost wholly of statistical data and contains very few comments or criticisms upon any of the works described. It would seem as though its usefulness might be largely increased by an analysis of many of the structures, showing wherein their strong and weak points lie, and why they do or do not represent good practice. Some matters which would be of great interest, such as the flood which Professor Williams's Ithaca dam successfully withstood during construction, are not mentioned.

With all this, however, this book contains an immense amount of valuable information and should have a place in the library of every hydraulic engineer. The plates showing comparative sections of the more important masonry dams all over the world, drawn to a single scale, and similar sections of a few large earthern dams, and the table giving cost of reservoir construction per acre-foot of capacity, are especially valuable. It would seem that this table might well be extended by the addition of another column showing the cost per million gallons of capacity, for the benefit of eastern engineers, who never have occasion to work in acre-feet.

Some doubt is, however, thrown on the accuracy of this table by the fact that the cost of the Wachusett Reservoir is here taken as the cost of the Wachusett dam only, neglecting not only the cost of stripping and preparing the reservoir bottom, — which might perhaps well be omitted in a comparison with other reservoirs where no such preparation was made, — but also

the cost of the two dikes, which in effect constituted sections of the dam, equally necessary as the main dam in the construction of a reservoir of the capacity stated.

Most of the illustrations are very good. The book is well printed on good paper, and, considering that it is in effect a new book, contains few typographical errors. It has a good index.

PUBLIC WATER SUPPLIES. By F. E. Turneaure and H. L. Russell, professors in the University of Wisconsin, with a chapter on Pumping Machinery by D. W. Mead, professor of Hydraulic and Sanitary Engineering, University of Wisconsin. Second edition, revised and enlarged. 808 pp. 6 x 9 inches. New York: John Wiley & Sons. 1908. $5.00.

The first edition of this book appeared in 1901; it has now been revised and brought up to date in illustrating the best modern practice in water-works engineering. The changes in current practice since the first edition have, of course, been most marked in water purification works, but are also of considerable moment in all branches.

This book is primarily a textbook, and a most admirable one. It is designed especially for the use of students in engineering schools. It is, however, none the less valuable as a book of reference for the practicing engineer and water-works man.

To even list the contents of this work as indicated by the chapter headings would occupy more space than is available for this review. It may be stated that the whole subject of water-supply engineering is covered as fully as is possible in the space available, starting with an historical sketch of the development of water-works systems; following with an outline of the quantity of water required and sources of supply; quality of water and examination of supplies; the general principles of water-works design (including a chapter containing substantially all the formulas of hydraulics which are likely to be needed in such works); descriptions of works for the collection, purification, and distribution of water, including pumping machinery; and a few remarks upon general financial considerations in the operation of water works. It may be noted that the application of the principles of economy in the problem of design is also discussed with a reasonable degree of fullness.

Periodical literature has been drawn upon in large measure in preparing much of the matter. It is a satisfaction to note many references to the JOURNAL of this Association, and particularly that the patterns of the Association's Standard Specifications for Cast-Iron Pipe and Special Castings are quoted in some detail. The references are very full, both in the text and in the bibliography which is appended to each chapter.

The book is well illustrated, mostly by reproductions of drawings. The typography and paper are good and the makeup of the volume in every way satisfactory. It is by all odds the most comprehensive and satisfactory single book upon the subject of water works published in the United States, and should be in every water-works library.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT,—the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

Table of Contents.

INDEX TO ADVERTISEMENTS.

(*Index continued on page xxviii.*)

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